720A

Kelvin-Varley Voltage Divider

Instruction Manual

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FLUKE ®

~~Rev. 8/93~~ update 1 yr.

5/94

WARRANTY

Notwithstanding any provision of any agreement the following warranty is exclusive:

The JOHN FLUKE MFG. CO., INC., warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of 1-year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, disposable batteries (rechargeable type batteries are warranted for 90-days), or any product or parts which have been subject to misuse, neglect, accident, or abnormal conditions of operations

In the event of failure of a product covered by this warranty, John Fluke Mfg. Co., Inc., will repair and calibrate an instrument returned to an authorized Service Facility within 1 year of the original purchase; provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option. replace the product in lieu of repair. With regard to any instrument returned within 1 year of the original purchase, said repairs or replacement will be made without charge. If the failure has been caused by misuse, neglect, accident, or abnormal conditions of operations, repairs will be billed at a nominal cost. In such case, an estimate will be submitted before work is started, if requested

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED. INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS, OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. JOHN FLUKE MFG. CO., INC., SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT, TORT, OR OTHERWISE

If any failure occurs, the following steps should be taken:

1. Notify the JOHN FLUKE MFG. CO., INC., or nearest Service facility, giving full details of the difficulty, and include the model number, type number and serial number. On receipt of this information, service data, or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument, transportation prepaid. Repairs will be made at the Service Facility and the instrument returned, transportation prepaid.

SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT

All shipments of JOHN FLUKE MFG. CO., INC., instruments should be made via United Parcel Service or "Best Way"* prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER

The instrument should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact the nearest Fluke Technical Center.) Final claim and negotiations with the carrier must be completed by the customer.

The JOHN FLUKE MFG. CO., INC, will be happy to answer all applications or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: JOHN FLUKE MFG. CO., INC., P.O. BOX C9090, EVERETT, WASHINGTON 98206, ATTN: Sales Dept. For European Customers: Fluke (Holland) B.V., P.O. Box 5053, 5004 EB, Tilburg, The Netherlands.

*For European customers, Air Freight prepaid.

John Fluke Mfg. Co., Inc., P.O. Box C9090, Everett, Washington 98206

Rev. 6/81

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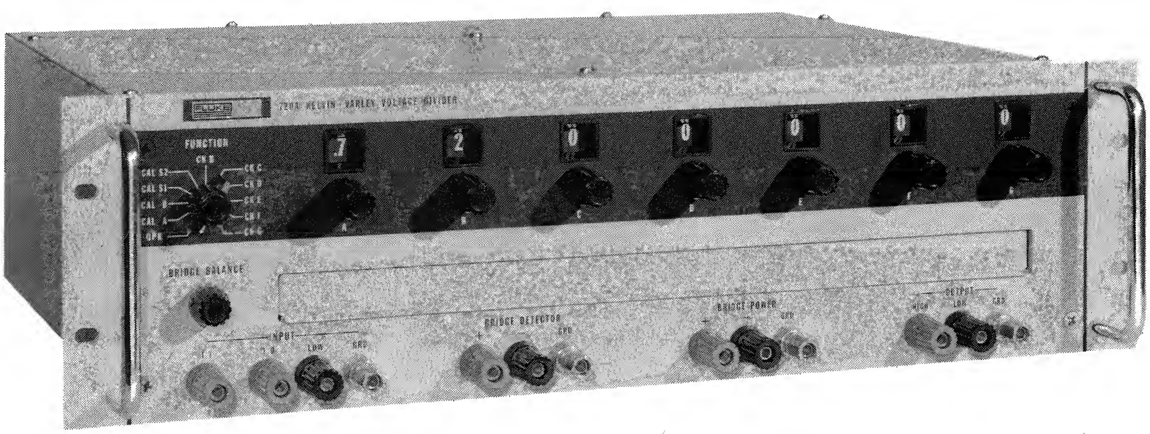


MODEL 720A KELVIN-VARLEY VOLTAGE DIVIDER

Section 1

Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 720A Kelvin-Varley Voltage Divider is a seven-dial primary ratio standard which meets the most exacting requirements of the standards laboratory. Absolute linearity of 0.1 ppm, temperature coefficient of linearity of 0.1 ppm/°C, and self-calibration make the 720A the most accurate instrument available for the comparison of primary and secondary voltage and resistance standards. The linearity has a small power derating coefficient of 0.2 ppm per watt which is achieved by matching the resistors' temperature coefficients close to zero. This permits operation at up to 1100 volts and 11 watts.

1-3. The Model 720A has two high input terminals. The terminal labeled INPUT 1.0 is for general use in all Kelvin-Varley applications for which direct reading, in ratio, is desired. The terminal labeled INPUT 1.1 is used for voltage measurement applications when both direct reading in voltage and over-ranging are desired. An example of this application is the measurement of standard cell voltages. Use of the 1.1 INPUT at a level of 1.1 volts in this application results in divider resolution of 0.1 microvolt and allows comparison of standard cells to within 1 microvolt.

1-4. Only thoroughly aged resistors of the highest quality are used in the Model 720A Kelvin-Varley Divider. As a result, linearity change per year will not exceed one part per million unless the instrument is subjected to abuse. To assure that the divider remains within its specifications throughout its useful life, adjustments are provided for the resistors of the first three decades. The third decade adjustments normally will be used only during annual calibration. Performing the self calibration procedure sets the adjustments of the first two decades. With reasonable care these adjustments will provide instrument accuracy of 0.1 part per million at the time of adjustment.

1-5. ELECTRICAL SPECIFICATIONS

RATIO RANGE
0 to 1.0 (1.0 INPUT TAP) and 0 to 1.1 (1.1 INPUT TAP).

RESOLUTION
0.1 ppm of input with 7 decades.

ABSOLUTE LINEARITY
(at calibration temperature and without the use of a correction chart)*
±0.1 ppm of input at dial settings of 1.1 to 0.1.
±0.1 $(10S)^{1/3}$ of input at dial settings (S) of 0.1 to 0.
(See Figure 1-1.)

ABSOLUTE LINEARITY STABILITY (without self-calibration)
±1.0 ppm of input/year at dial settings of 1.1 to 0.1.
±1.0 $(10S)^{2/3}$ ppm of input/year at dial settings (S) of 0.1 to 0.
(See Figure 1-2.)

NOTE!

The self-calibration procedure may be used at any time to reset absolute linearity to ±0.1 ppm of input.

TEMPERATURE COEFFICIENT OF LINEARITY
±0.1 ppm of input/°C maximum at dial settings of 1.1 to 0.1.
(See Figure 1-3.)

SHORT-TERM LINEARITY STABILITY
Under typical conditions in a standards laboratory environment (temperature maintained within ±1°C) and with an applied voltage of up to 100 volts, stability of linearity is 0.1 ppm/30 days.

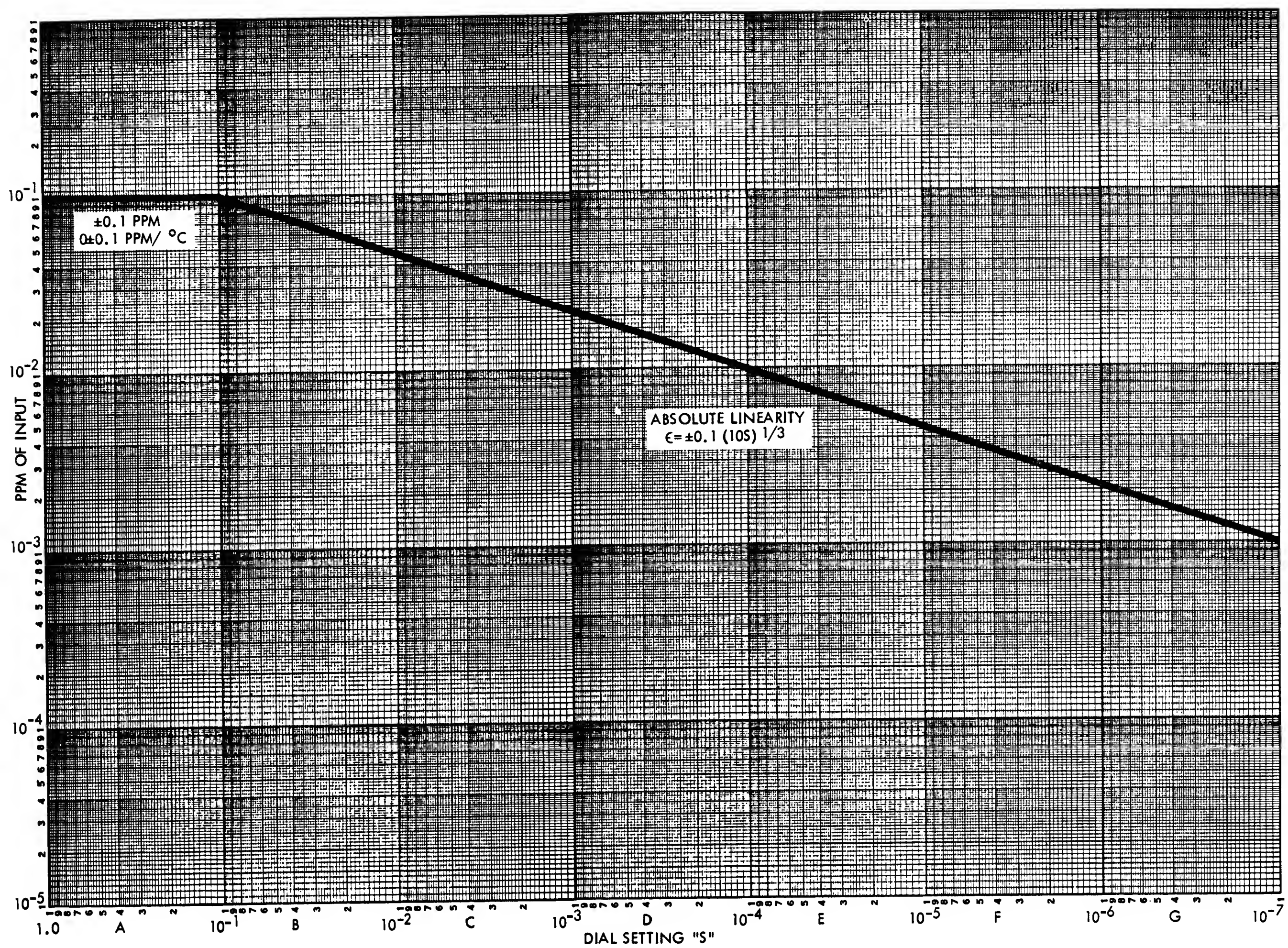


Figure 1-1. ABSOLUTE LINEARITY

POWER COEFFICIENT OF LINEARITY
±0.2 ppm of input/watt maximum at dial settings of 1.1 to 0.1.
±0.2 $(10S)^2$ ppm of input/watt maximum at dial settings (S) of 0.1 to 0.
(See Figure 1-4.)

MAXIMUM END ERRORS

Zero error, at output low	0.004 ppm of input
Zero error, at input low	0.05 ppm of input
Full-scale error	0.05 ppm of input

THERMAL VOLTAGES
±0.5 uv maximum.

MAXIMUM INPUT POWER
10 watts on 1.0 INPUT terminal.
11 watts on 1.1 INPUT terminal.

*Absolute linearity is defined as the linearity between maximum and minimum output voltages.

MAXIMUM INPUT VOLTAGE
1000 volts on 1.0 INPUT terminal.
1100 volts on 1.1 INPUT terminal.

BREAKDOWN VOLTAGE
2000 volts to case at 10,000 feet.
2500 volts to case at sea level.

INPUT RESISTANCE
100 kilohms ±0.005% at 1.0 INPUT terminal at 25°C.
110 kilohms ±0.005% at 1.1 INPUT terminal at 25°C.

TEMPERATURE COEFFICIENT OF INPUT RESISTANCE
±1 ppm/°C maximum.

MAXIMUM OUTPUT RESISTANCE
66 kilohms.

1-6. MECHANICAL AND ENVIRONMENTAL SPECIFICATIONS

OPERATING TEMPERATURE RANGE
0°C to 50°C (32°F to 122°F).

NOTE!

When the Model 720A is used at temperatures below 15°C (59°F) or above 35°C (95°F), the range of the calibration adjustments may be

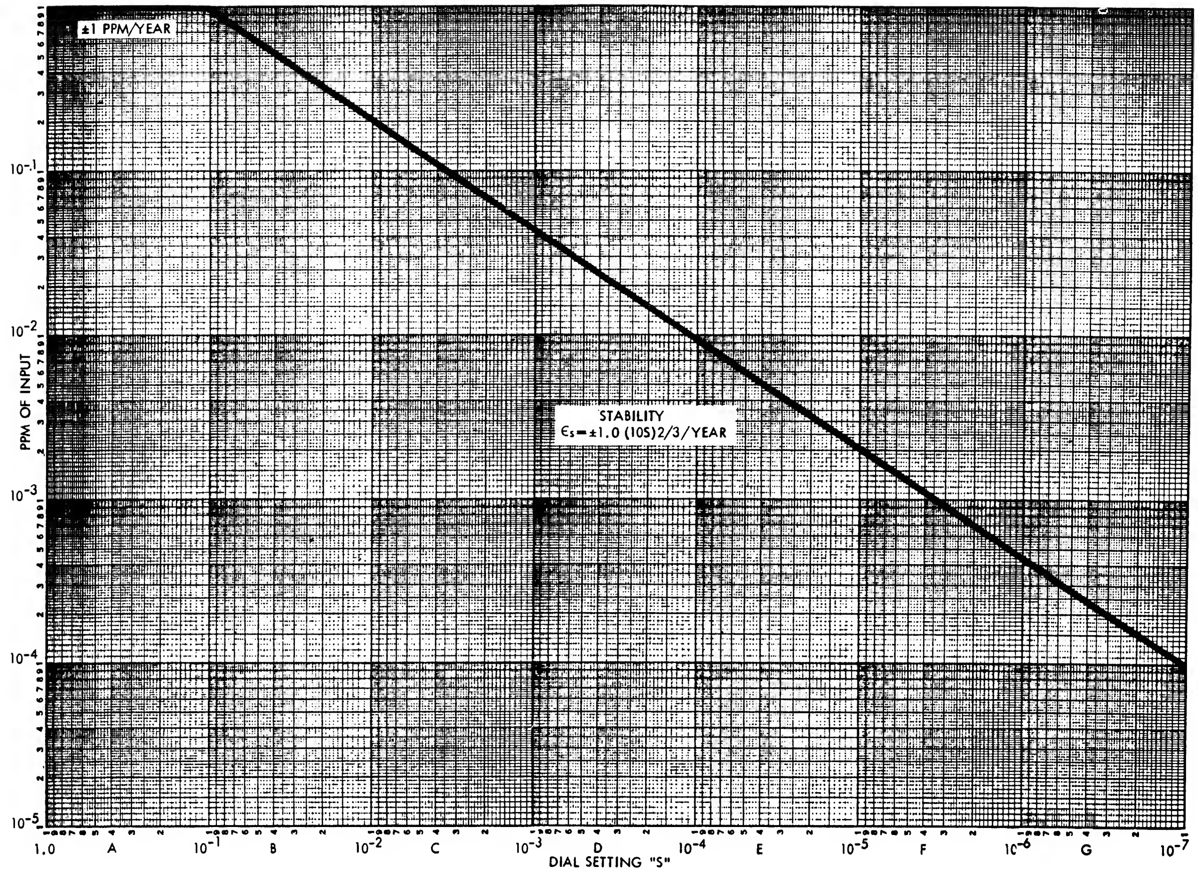


Figure 1-2. STABILITY

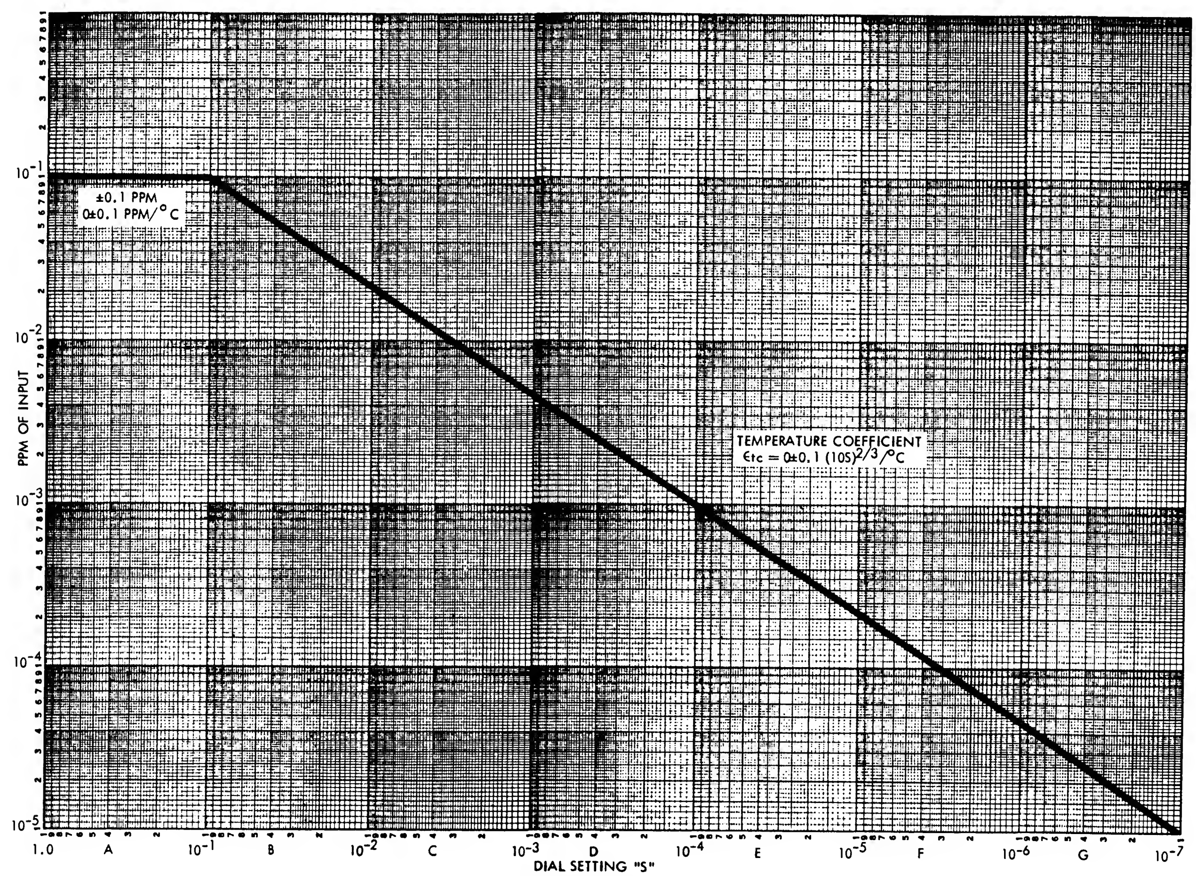


Figure 1-3. TEMPERATURE COEFFICIENT

exceeded and linearity must be derated 0.1 ppm/°C from the calibration temperature.

OPERATING HUMIDITY RANGE
Up to 70% relative humidity at 35°C (95°F): No derating is required.
Up to 80% relative humidity at 35°C (95°F): Linearity derating is 0.1 ppm of input for any relative humidity between 70% and 80%.

STORAGE TEMPERATURE RANGE
-34°C to 70°C (-29°F to 158°F).

SHOCK
Meets requirements of MIL-T-945A and MIL-S-901B, rigidly mounted with slides.

VIBRATION
Meets requirements of MIL-T-945A, rigidly mounted or rack mounted with slides.

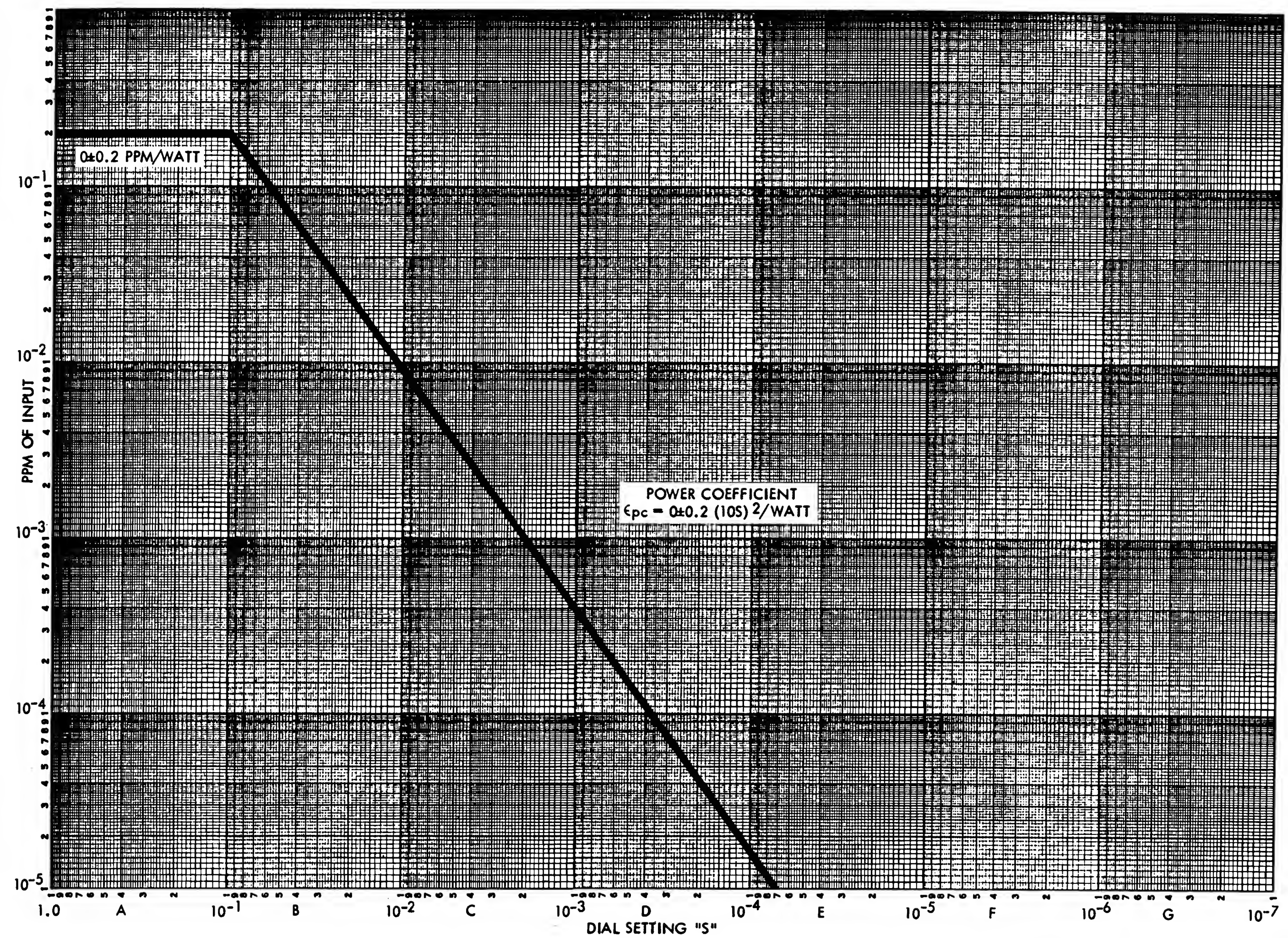
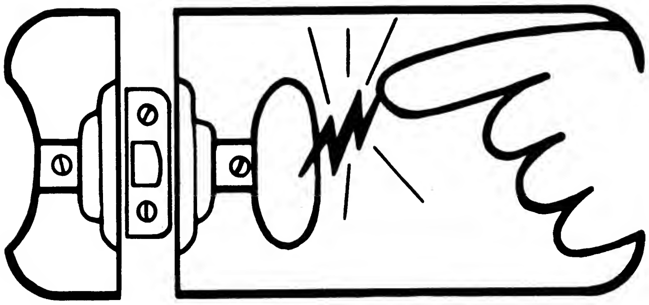


Figure 1-4. POWER COEFFICIENT

static awareness

A Message From

John Fluke Mfg. Co., Inc.



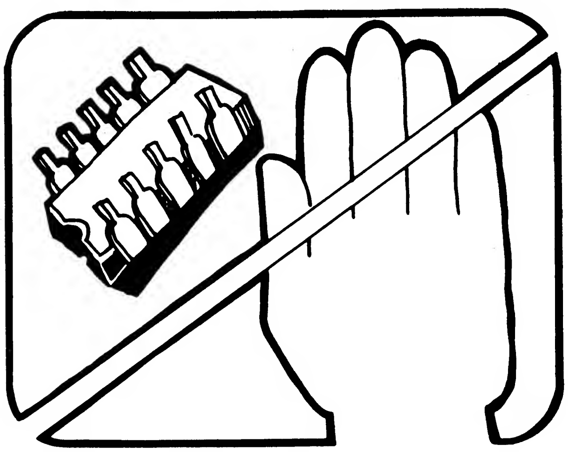
Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

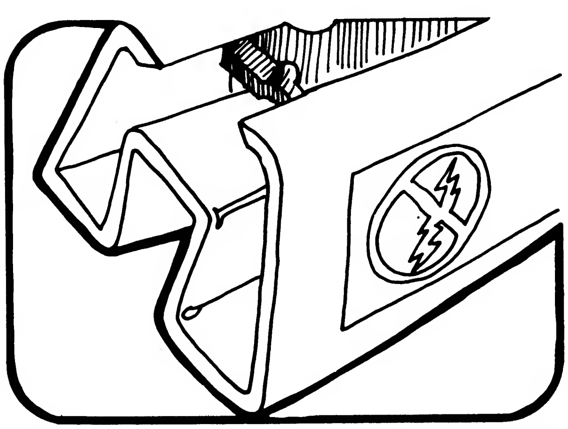
The Static Sensitive (S.S.) devices are identified in the Fluke technical manual parts list with the symbol

" "

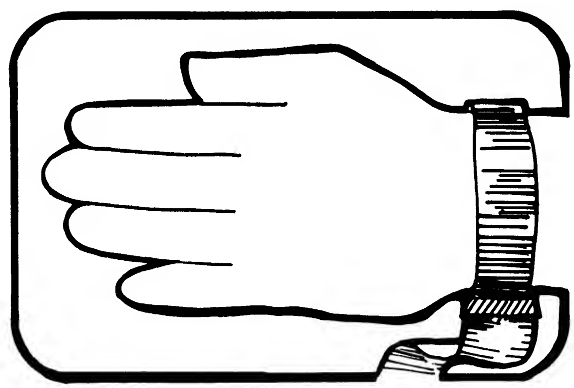
The following practices should be followed to minimize damage to S.S. devices.



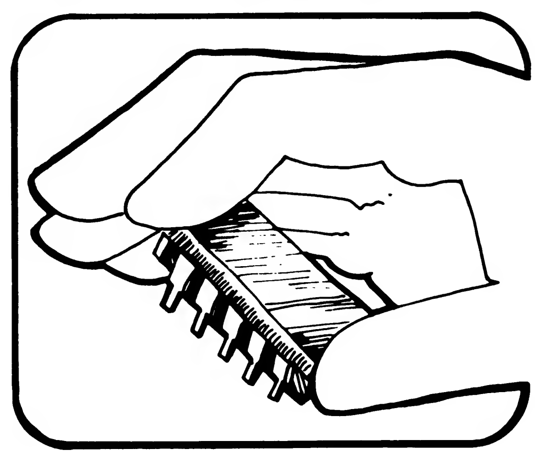
1. MINIMIZE HANDLING



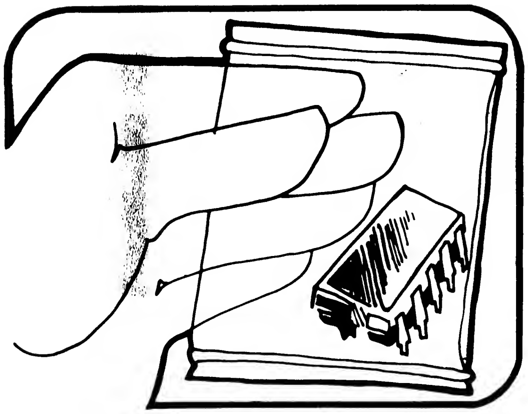
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



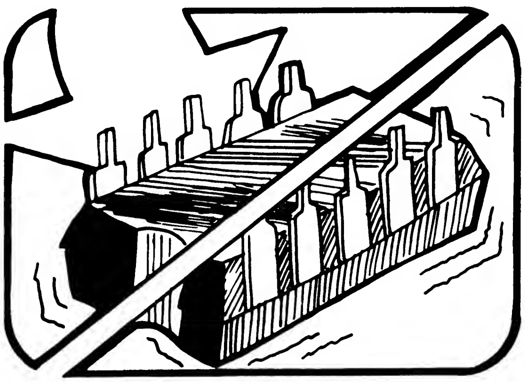
3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES. USE A HIGH RESISTANCE GROUNDING WRIST STRAP.



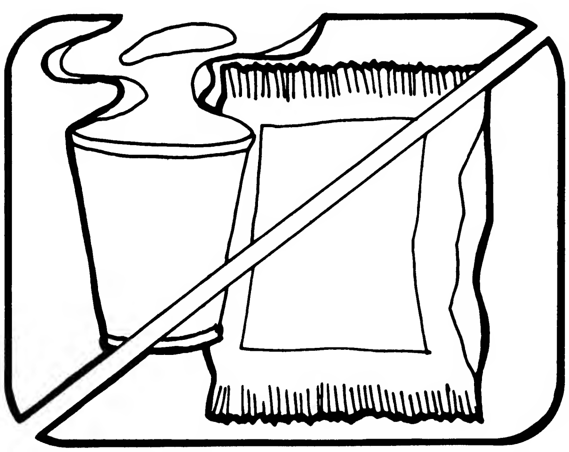
4. HANDLE S.S. DEVICES BY THE BODY



5. USE STATIC SHIELDING CONTAINERS FOR HANDLING AND TRANSPORT



6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL AND STYROFOAM® IN WORK AREA

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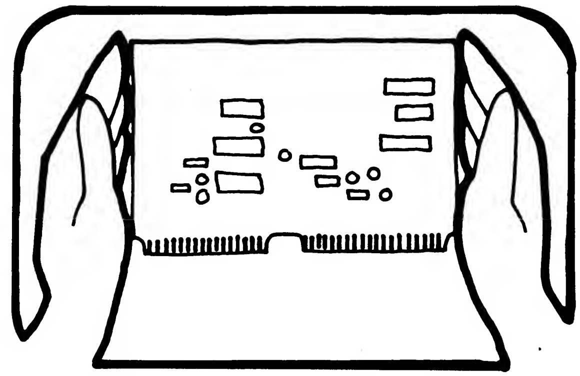
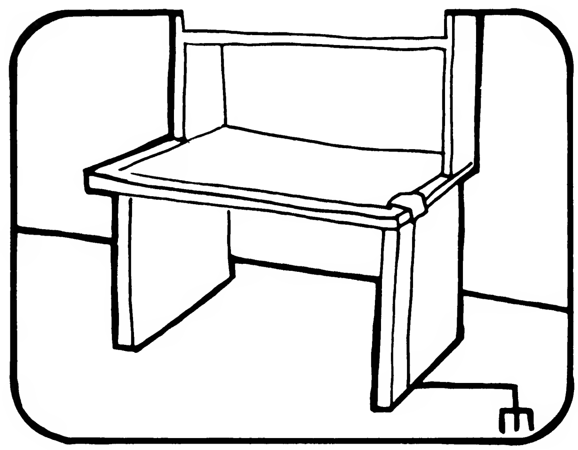


8. WHEN REMOVING PLUG-IN ASSEMBLIES, HANDLE ONLY BY NON-CONDUCTIVE EDGES AND NEVER TOUCH OPEN EDGE CONNECTOR EXCEPT AT STATIC-FREE WORK STATION. PLACING SHORTING STRIPS ON EDGE CONNECTOR HELPS TO PROTECT INSTALLED SS DEVICES.



9. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION

10. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.

11. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

A complete line of static shielding bags and accessories is available from Fluke Parts Department, Telephone 800-526-4731 or write to:

JOHN FLUKE MFG. CO., INC.
PARTS DEPT. M/S 86
9028 EVERGREEN WAY
EVERETT, WA 98204

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Section 2
Operating Instructions

2-1. INTRODUCTION

2-2. Although the Model 720A is a primary ratio standard it has the versatility necessary for use in a wide variety of measurement and control applications. In most applications the divider is used as an element of a system for measuring ratios, voltages, or resistances.

2-3. POWER LIMITATIONS

2-4. It is possible to damage the Model 720A by applying voltages incorrectly to the input terminals or by drawing more than 11 milliamperes from the output tap. The instrument will be damaged if a potential greater than 200 volts is applied between the 1.0 INPUT terminal and the 1.1 INPUT terminal. To prevent damage caused by drawing excessive current from the output tap, either the input or the output can be fused for 11 milliamperes. Another method of protecting the instrument is through the use of a power supply with current limiting capability. The current limit should be set for 11 milliamperes or less.

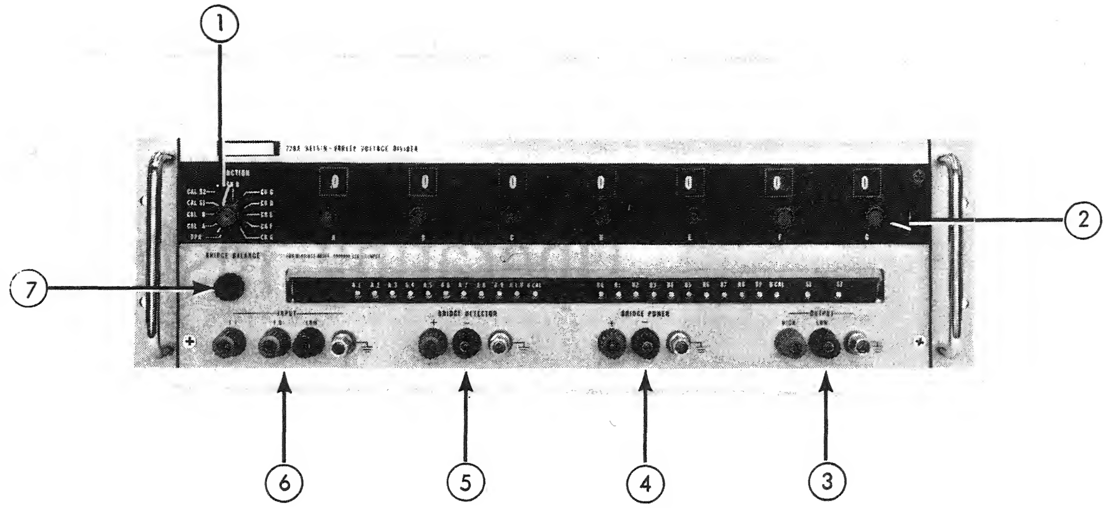
2-5. FUNCTIONS OF CONTROLS AND TERMINALS

2-6. Figure 2-1 shows the controls and terminals of the Model 720A and describes their functions.

2-7. RATIO ERRORS CAUSED BY LOADING OR LEAKAGE

2-8. Measurements of any kind require a knowledge of the errors associated with the equipment used to perform the measurement. Measurement made with the Model 720A are not different.

2-9. One very important source of error in measurements employing the Model 720A is the effect that external load and leakage resistances have on overall accuracy. If excessive current is drawn from the divider output tap because of loading or leakage, linearity errors which far exceed the linearity specifications can result. For this reason, Kelvin-Varley dividers customarily are used in null-balance systems in which minimum current is drawn from the divider output tap.



1	FUNCTION SWITCH	Places instrument in operating mode, or performs internal switching for calibration, or performs internal switching for decade linearity test.
2	DIALS	Decade switches are used to set the ratio of output to input (division ratio).
3	OUTPUT TERMINALS	Provide output voltage of the divider. LOW OUTPUT terminal is connected to LOW INPUT terminal through low compensating resistance.
4	BRIDGE POWER TERMINALS	Used to connect the bridge power for calibration. BRIDGE POWER (-) terminal is used for low input during decade linearity testing.
5	BRIDGE DETECTOR TERMINALS	Used to connect null detector for calibration.
6	INPUT TERMINALS	Used to connect the input voltage across the resistance of the divider.
7	BRIDGE BALANCE CONTROL	Used to balance bridge during self-calibration and calibration.

Figure 2-1. FUNCTIONS OF CONTROLS AND TERMINALS

2-10. Loading Errors

2-11. Figure 2-2 illustrates the Thevinin equivalent for the Model 720A Kelvin-Varley Divider.

To calculate the error in output voltage, as a fraction of the input voltage, the following expressions are given.

$$E_o\,(1+\epsilon_o) = \frac{S(1+\epsilon)\;E_{IN}\,R_L}{R_L+R_o}$$

but $E_o = SE_{IN}$

therefore $$(1+\epsilon_o) = \frac{(1+\epsilon)\,R_L}{R_L+R_o}$$

If $R_L \gg R_o$ and $\left(1+\dfrac{R_o}{R_L}\right)$ is expanded in series

then

$$(1+\epsilon_o) = (1+\epsilon)\left[1-\frac{R_o}{R_L}+\left(\frac{R_o}{R_L}\right)^2-\left(\frac{R_o}{R_2}\right)^3+\ldots\ldots\right]$$

$$\cong (1+\epsilon)\;\left(1-\frac{R_o}{R_L}\right)$$

$$\epsilon_o \cong \quad \epsilon - \frac{R_o}{R_L}$$

and $$\epsilon_L \cong \frac{R_o}{R_L}$$

Converting to errors expressed as a fraction of the input voltage the expression becomes:

$$\epsilon'_O = \epsilon' - \frac{S\,R_O}{R_L}$$

If the 1.1 INPUT terminal is used then:

$$E_O = \frac{S}{1.1}\,E_{IN}$$

and:

$$\epsilon'_O \cong \epsilon' - \frac{S R_O}{1.1\,R_L}$$

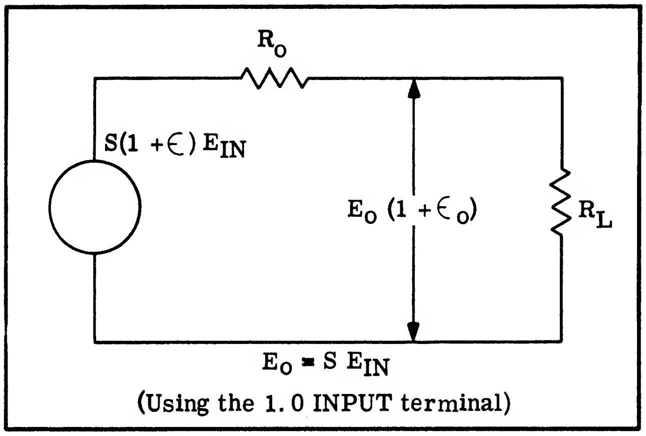


Figure 2-2. THEVININ EQUIVALENT CIRCUIT

2-12. The following list of definitions are given for the terms used in the preceding paragraphs.

a. E_O - Nominal output voltage.

b. E_{IN} - Input voltage.

c. ϵ_O - Error in output voltage as a fraction of output.

d. ϵ - Divider linearity error as a fraction of output.

e. ϵ_L - Loading error as a fraction of output.

f. ϵ'_O - Error in output voltage as a fraction of input.

g. ϵ' - Divider linearity error as a fraction of input.

h. ϵ'_L - Loading error as a fraction of input.

i. S - Divider dial setting.

j. R_O - Divider output resistance.

k. R_L - Load resistance (including leakage resistance from the tap terminal to the divider input terminal).

2-13. Output Resistance Versus Loading

2-14. The graph in Figure 2-3 illustrates the approximate variation of output resistance with the dial setting for both the 1.0 and 1.1 INPUT terminals. This resistance is measured by shorting the input high and input low terminals and measuring the resistance between the output high and low terminals. When computing correction factors for loading of a particular instrument do not use the approximate resistance values given by Figure 2-3. Instead, measure the output resistance at the desired dial setting. The maximum amount of loading which will still be negligible for any dial setting may be calculated as follows:

a. Divider specification = 0.1 ppm of input.

b. Maximum loading error limit = 0.03 ppm of input.

c. $\frac{S\,R_O}{R_L} = \epsilon_L = 0.3 \times 10^{-8}$

d. Maximum R_O = 66 kilohms when S = .454.

e. Minimum $R_L = \frac{S\,R_O}{\epsilon_L} = \frac{(.454)\,(6.6 \times 10^4)}{3 \times 10^{-8}}$

$= 1 \times 10^{12}$ ohms.

2-15. Similar calculations have been made for other dial settings and the results have been plotted in Figure 2-4. The choice of a loading error limit of 0.03 ppm was, of course, arbitrary and should vary over a wide range for different measurement applications. In general, the error should be calculated and allowances made unless the errors are small compared to either the desired measurement accuracies or the divider specifications.

2-16. It should be noted that resistances calculated are the parallel combinations of the load resistor and any leakage resistances which may exist from the tap point (OUTPUT HIGH terminal) to the input terminals of the divider.

2-17. In applications where the load resistance must be supplied with a current, this current may be supplied by either a stable power supply or a second voltage divider in parallel with the measurement divider.

2-18. TEMPERATURE CONTROL

2-19. Because of slight differences in temperature coefficients of the resistors used in the Model 720A, the linearity of the divider will vary with ambient temperature. This change in linearity will never exceed ±0.1 ppm of input per degree centigrade for dial settings above 0.1, and typically will be 0.05 ppm/°C. For measurement applications which require the best possible accuracy, temperature and temperature variations must be considered. The operating temperature should be within 1°C of the self-calibration temperature if at all possible. If the desired operating temperature is

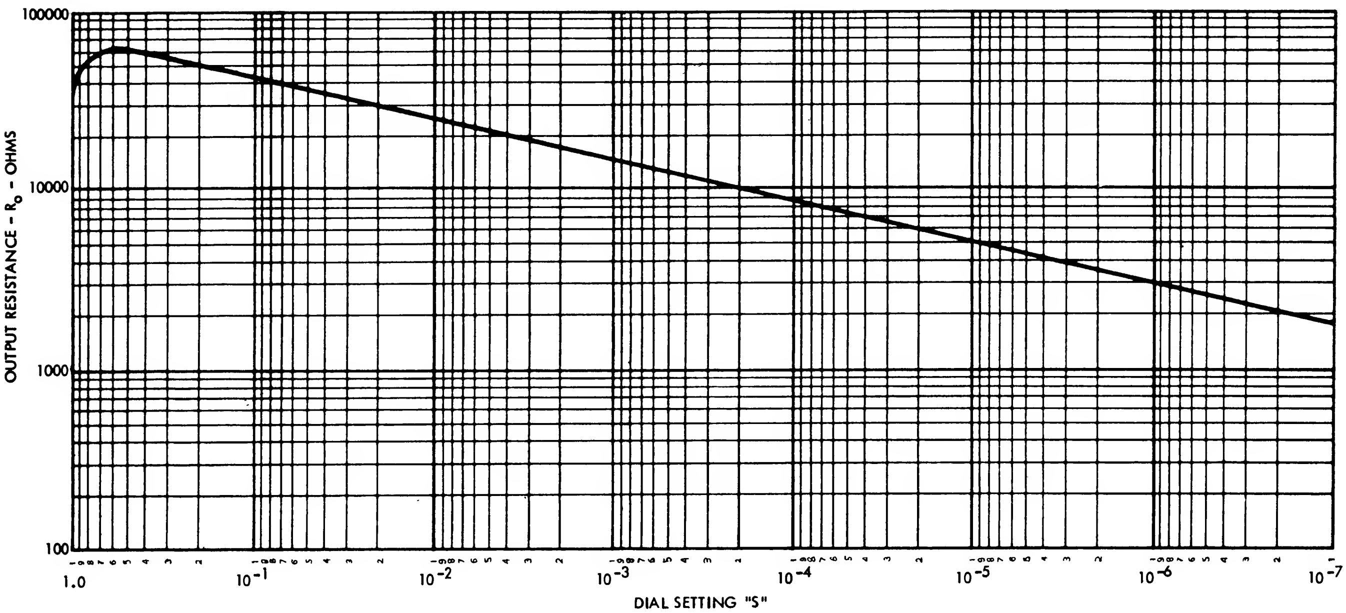


Figure 2-3. APPROXIMATE VARIATION OF OUTPUT RESISTANCE WITH DIAL SETTING

appreciably different from the last calibration temperature, the instrument should be allowed to stabilize at the operating temperature and then the self-calibration procedure should be performed to adjust linearity to 0.1 ppm of input. The Model 720A is factory tested at a temperature of 23 ±1°C.

2-20. POWER COEFFICIENT

2-21. The power coefficient will not exceed 0.2 ppm per watt of input power and typically will be 0.1 ppm per watt or less. With high-voltage applied, self-heating will cause the linearity of the instrument to drift. This drift may continue for as long as four hours after application of the high voltage. Low-voltage, high-accuracy measurements (0.1 ppm) should not be attempted immediately after high-voltage use. Each time the setting of the "A" decade is changed, the power distribution in it is changed because the current through the instrument is divided between the two shunted resistors of the "A" decade and the resistance of the other decades which shunts them. Because of this current division, the two shunted resistors do not become as hot as the other resistors in the "A" decade. The change in current distribution brought about by changing the setting of the "A" decade causes linearity to drift for a few minutes if high voltage is applied.

2-22. END ERRORS

2-23. When the Model 720A is compared to another divider, and a lead compensator such as the Fluke Model 721A is used, absolute linearity may be used directly without correction for end errors. In other applications, the use of a lead compensator is not practical and end error corrections must be applied. Use the following procedure to determine the end error corrections for the Model 720A:

a. Connect the equipment as shown in Figure 2-5 (A).

b. Adjust the input voltage to 1000 volts.

c. With all dials set to zero, measure the voltage between the OUTPUT HIGH terminal and the INPUT LOW terminal. This is the zero error at input low. One microvolt equals 0.001 ppm.

d. Connect the equipment shown in Figure 2-5 (B).

e. Adjust the input voltage to 1000 volts.

f. With all dials set to zero, measure the voltage between the OUTPUT HIGH and OUTPUT LOW terminals. This is the zero error at output low. One microvolt equals 0.001 ppm.

g. Connect the equipment as shown in Figure 2-5 (C).

h. Adjust the input voltage to 1000 volts.

i. With dials set to 999999X, measure the voltage between the OUTPUT HIGH and 1.0 terminals. This is the full-scale error. One microvolt equals 0.001 ppm.

j. Maintain the test set up of Figure 2-5 (C) except move the two leads connected to the 1.0 INPUT terminal to the 1.1 INPUT terminal.

k. Adjust the input voltage to 1000 volts.

l. With all dials set to 1.0 09999X, measure the voltage between the OUTPUT HIGH and 1.1 INPUT terminals. One microvolt equals 0.001 ppm.

2-24. SELF-CALIBRATION PROCEDURE

2-25. Performing this self-calibration procedure adjusts the step resistance and overall resistance of the

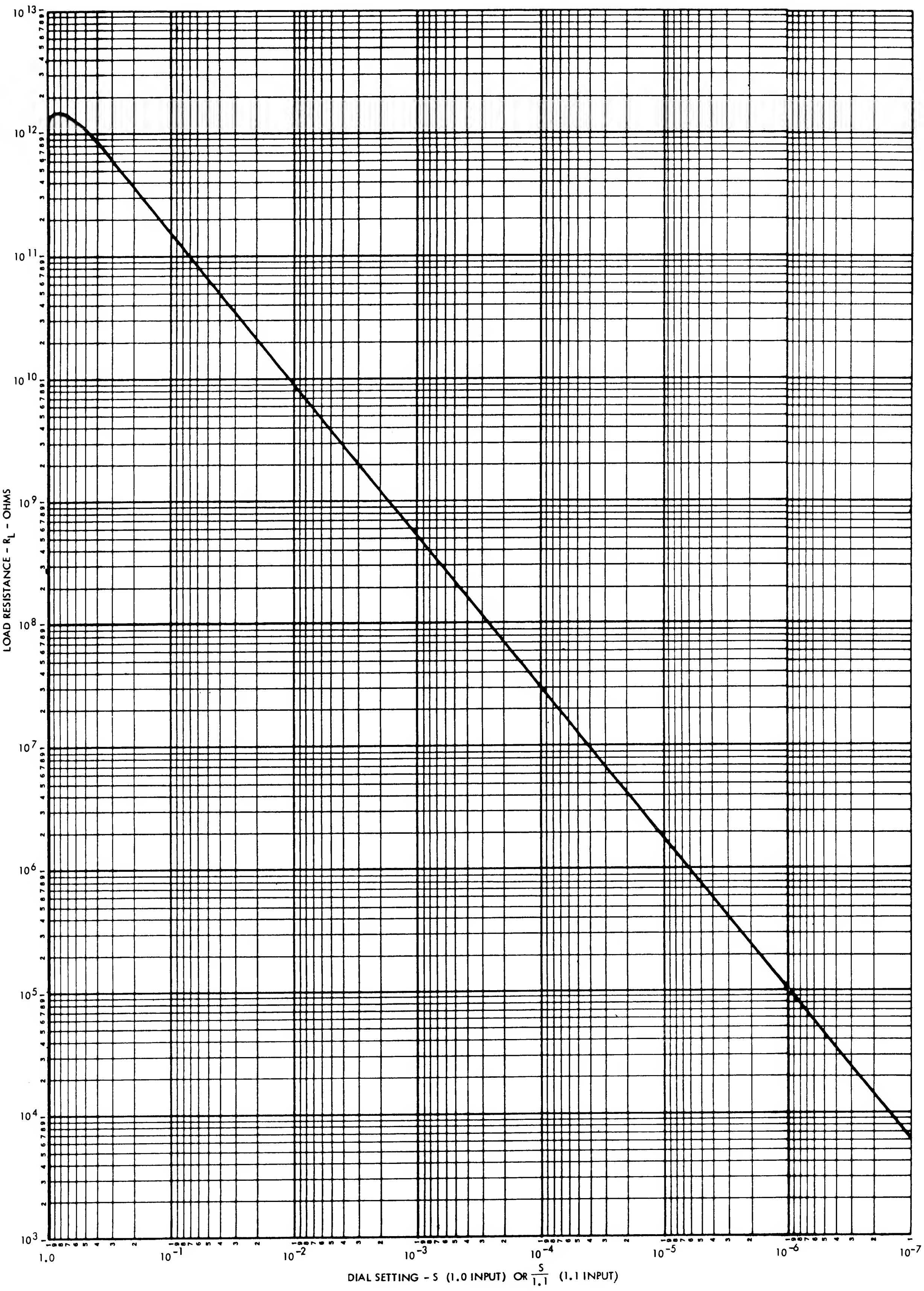


Figure 2-4. APPROXIMATE VARIATION OF MINIMUM LOAD RESISTANCE FOR 0.03 PPM OF INPUT LOADING ERROR

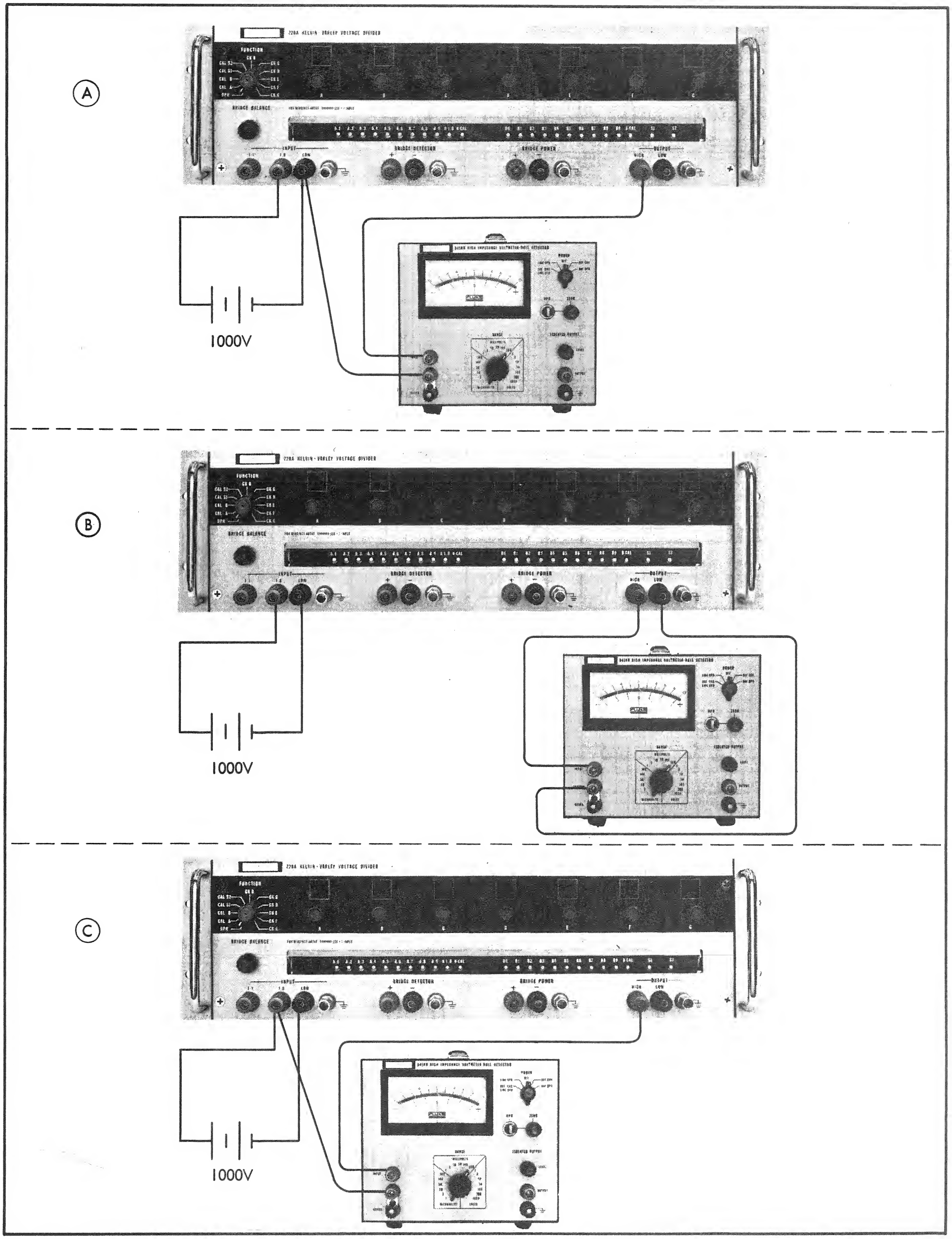


Figure 2-5. CONNECTIONS FOR DETERMINING END ERRORS

first two decades to compensate for any resistance changes caused by temperature changes or aging. Thus, the absolute linearity of the instrument is adjusted to 0.1 ppm of input. The only external test units required are a stable source of 10 volts and 20 volts such as the Fluke Model 412B and a sensitive null detector such as the Fluke Model 845AB. The procedure may be adapted easily to use batteries as the voltage source if a suitable dc power supply is not available. The procedure is as follows:

a. Connect the null detector (845AB) to the BRIDGE DETECTOR binding posts using low thermal leads.

b. On the Model 720A, set the FUNCTION switch to CAL A and the decade readout to .0000000.

c. On the Model 845AB, set the range switch to 10 microvolts; set the OPR ZERO switch to ZERO and adjust for zero meter deflection. Return the OPR-ZERO switch to OPR position.

d. Set the power supply (412B) for 20 volts output and connect it to the BRIDGE POWER binding posts.

e. Adjust the BRIDGE BALANCE control for a null indication on the Model 845AB.

f. Advance the "A" decade to 0.1, and adjust the associated variable resistor (A.1) to produce null, ±0.5 microvolts.

NOTE!

As the procedure is continued, occasionally return the "A" decade switch to zero and recheck bridge balance.

g. In turn, advance the "A" decade one position (A.2 through A CAL) and adjust the associated variable resistor.

h. Return the "A" decade to zero upon completion of the CAL position adjustment.

i. Set the power supply output to 10 volts.

j. Adjust the BRIDGE BALANCE to obtain a null.

k. Set the FUNCTION switch to CAL B, and adjust the associated variable resistor (BO) to produce a null ±1 microvolt.

NOTE!

As the procedure is continued, occasionally return the FUNCTION switch to CAL A and recheck bridge balance.

l. In turn, advance the "B" decade one position (B1 through B CAL) and adjust the associated variable resistor.

m. Return the "B" decade to zero upon completion of the CAL position adjustment.

n. Set the FUNCTION switch to CAL S1 and adjust variable resistor S1 for a null, ±1 microvolt.

o. Set the power supply to 20 volts.

p. Set the "A" decade to .0 and set the FUNCTION switch to CAL A.

q. Adjust the BRIDGE BALANCE control for a null.

r. Set the FUNCTION switch to CAL S2 and adjust variable resistor S2 for a null, ±0.5 microvolt.

s. Set the FUNCTION switch to OPR and disconnect the test units. The self-calibration is complete.

2-26. CHECK POSITIONS OF THE FUNCTION SWITCH

2-27. Check positions (CK B etc.) are provided on the FUNCTION switch to permit checking the linearity of each decade from the front panel. This linearity check is a maintenance procedure. It should not be undertaken as a part of operation.

2-28. APPLICATIONS OF THE MODEL 720A

2-29. The following paragraphs give general instructions and equipment connections for calibrating a voltage divider, measuring unknown voltages, and measuring unknown resistances. Although these are by no means

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector; John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Lead compensator; John Fluke Mfg. Co. Model 721A	Resolution of 0.1 milliohm.

Figure 2-6. TYPICAL ASSOCIATED EQUIPMENT FOR VOLTAGE DIVIDER CALIBRATION

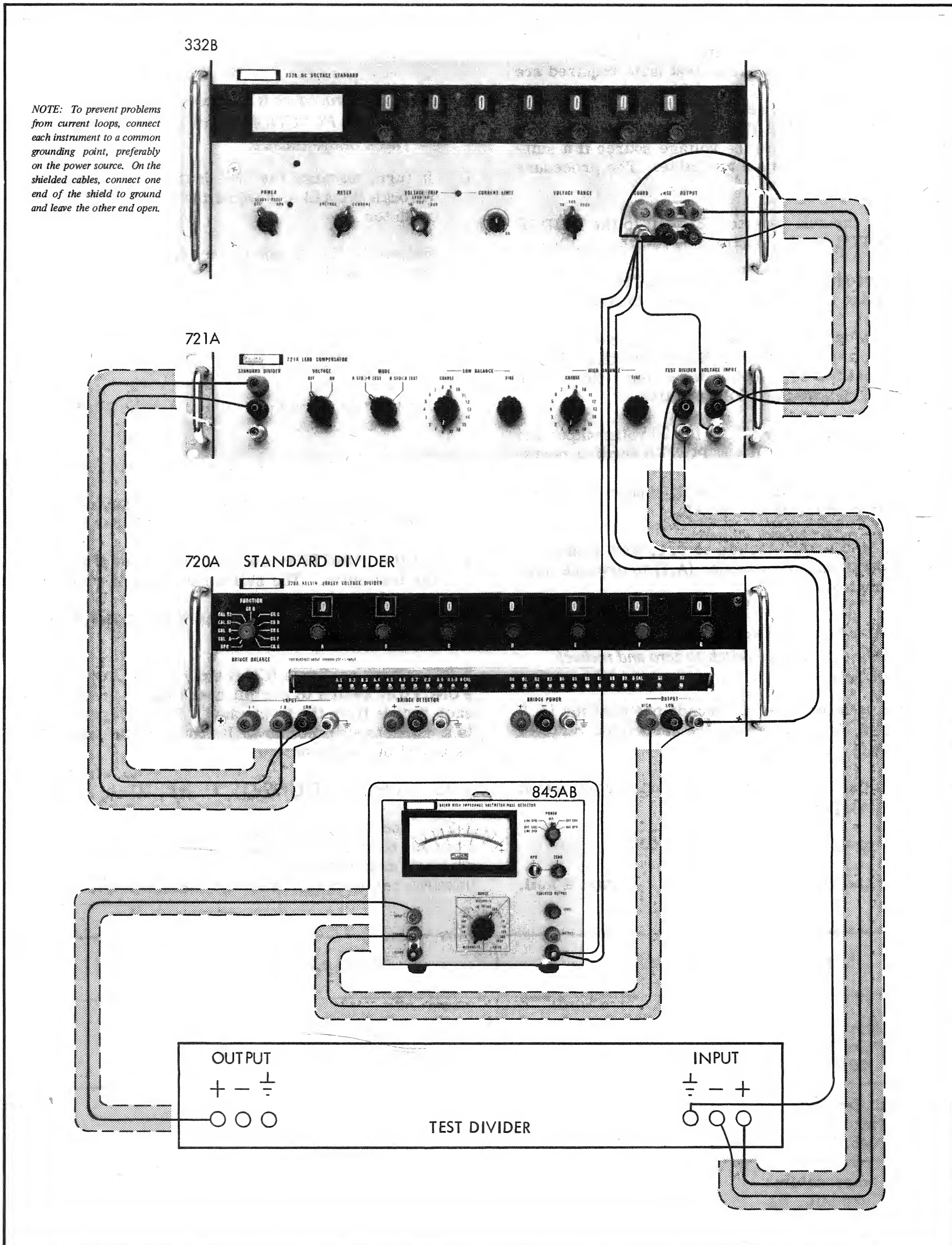


Figure 2-7. EQUIPMENT CONNECTIONS FOR CALIBRATING A VOLTAGE DIVIDER

the only applications of the instrument, they are the most common applications of a high-accuracy Kelvin-Varley divider such as the Model 720A.

2-30. Calibrating a Voltage Divider

2-31. The Model 720A in company with a dc voltage source, a null detector, and a lead compensator can be used to calibrate voltage dividers to an accuracy of 0.1 parts per million of input. Typical associated equipment for this application is listed in Figure 2-6. With this equipment, the full electrical capabilities of the Model 720A Kelvin-Varley Voltage Divider may be realized.

2-32. To calibrate a voltage divider, connect the equipment as shown in Figure 2-7 and proceed as follows:

NOTE!

Figure 2-8 is a schematic diagram of the test setup obtained by interconnecting the equipment as shown in Figure 2-7.

a. Set both dividers to zero.

b. Turn all equipment on and allow it to warm up until it reaches temperature equilibrium.

c. Place the null detector in zero mode, adjust it for zero deflection, and return it to operating mode.

d. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

e. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on, from saturating the null detector amplifier.

f. Set both dividers to full scale and adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

g. Set both dividers to zero and re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

h. Set both dividers to the first calibration point.

i. Observe the null detector and adjust the Model 720A to obtain a zero indication on the null detector. The difference between the setting of the Model 720A and the nominal value of the calibration point is the error of the divider being calibrated expressed as a decimal fraction of the input.

j. Find the error at each calibration point until the calibration is complete.

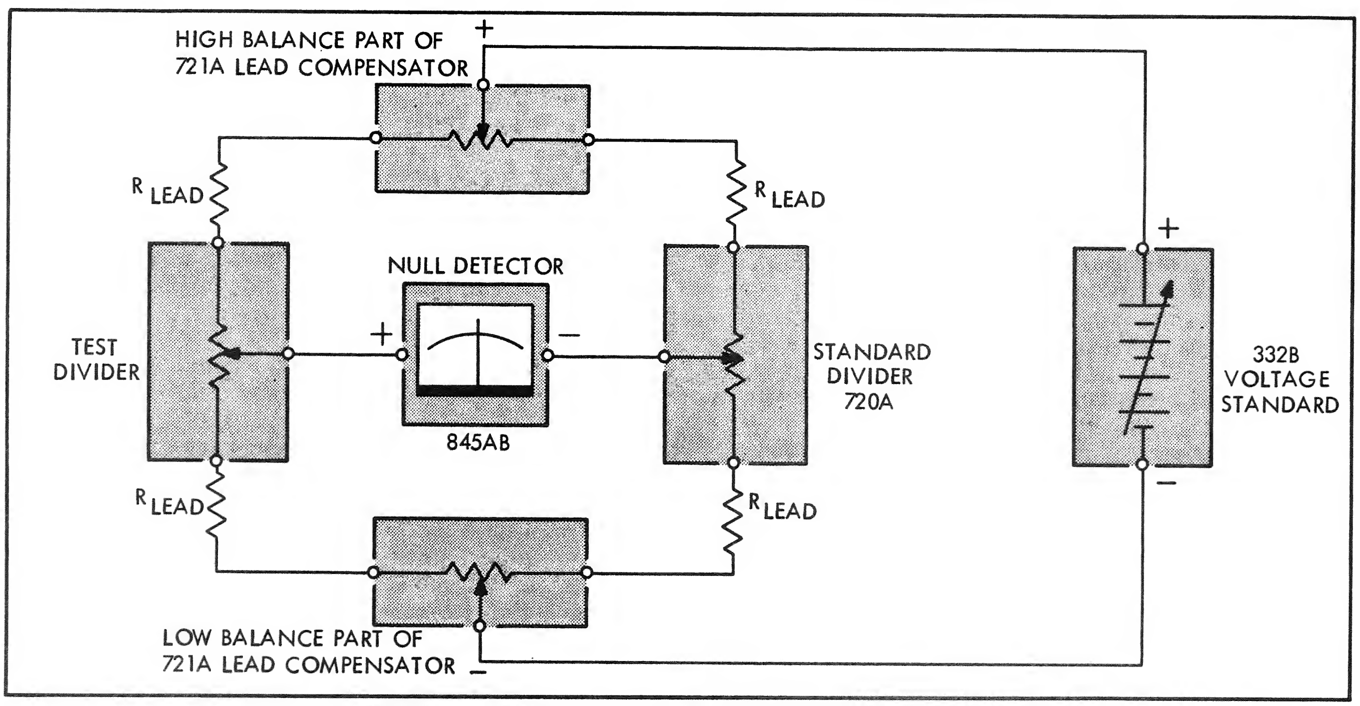


Figure 2-8. SIMPLIFIED SCHEMATIC DIAGRAM OF VOLTAGE DIVIDER CALIBRATION

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector (2 required); John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Standard Cell; Guildline Instruments Model 9152 or equivalent.	At least three saturated cells. Accuracy of 0.0005%.
DC Reference Voltage Divider; John Fluke Mfg. Co. Model 750A or equivalent.	Output accuracy of ±10 ppm. Input and output voltage. Rating of 1100V dc.

Figure 2-9. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN VOLTAGES

2-33. Measuring Unknown Voltages

2-34. The Model 720A in company with a stable dc voltage source, two null detectors, a standard cell, and a reference voltage divider may be used to measure an unknown voltage with high accuracy. Typical equipment for this application is listed in Figure 2-9. With this equipment the full electrical capabilities of the Model 720A may be realized.

2-35. To measure an unknown voltage, first connect the equipment as shown in Figure 2-10. The size of wire for leads A and B should be no smaller than No. 24 and the total length should be less than 3 feet. Then measure the approximate voltage by dialing the Model 720A to .0000000 and reading the null detector on the appropriate voltage range. Proceed as follows:

a. Open the standard cell voltage switch on the reference divider and set the standard cell voltage dials to the correct standard cell voltage.

b. Set the reference divider input switch to the first position higher than the voltage to be measured. Set the output switch to the same position.

c. Turn on all equipment and allow it to warm up until it reaches temperature equilibrium.

d. Set the standard cell switch of the reference divider to momentary position and adjust the output of the dc source to obtain a null indication on null detector number 1.

e. Adjust the readout dials of the Model 720A to obtain a null indication on null detector number 2.

f. Calculate the unknown voltage by multiplying the input voltage of the Model 720A by the numerical setting of the readout dials. For example, if the input voltage is 100 volts and the dial setting is .8903174, the unknown voltage is 89.03174 volts.

2-36. Simplified Method of Voltage Measurement

2-37. Voltages under 11 volts may be measured with comparable accuracy by the simpler equipment setup shown in Figure 2-12. This method standardizes the output voltage of the Model 720A by comparing it directly to a known standard cell. When used with an input of 1.1 volts, it is ideally suited to the accurate certification of standard cells. Typical associated equipment for this application is listed in Figure 2-11.

2-38. To measure the unknown voltages, connect the equipment as shown in Figure 2-12 and proceed as follows:

a. Set the dc voltage source for an output of eleven or 1.1 volts depending on the desired range and allow to warm up.

b. Set the readout dials of the Model 720A to the standard cell voltage.

c. Connect the standard cell in place of the unknown voltage and adjust the dc source to obtain a null indication on the null detector.

d. Disconnect the standard cell.

e. Set the readout dials of the Model 720A to the approximate value of the unknown voltage.

f. Connect the unknown voltage.

g. Adjust the readout dials of the Model 720A to obtain a null indication on the null detector.

h. Calculate the unknown voltage by multiplying by 10 or 1 depending on the range. For example, if the readout dials are set at .7500055 and the input is 11 volts, the unknown voltage is 7.500055 volts.

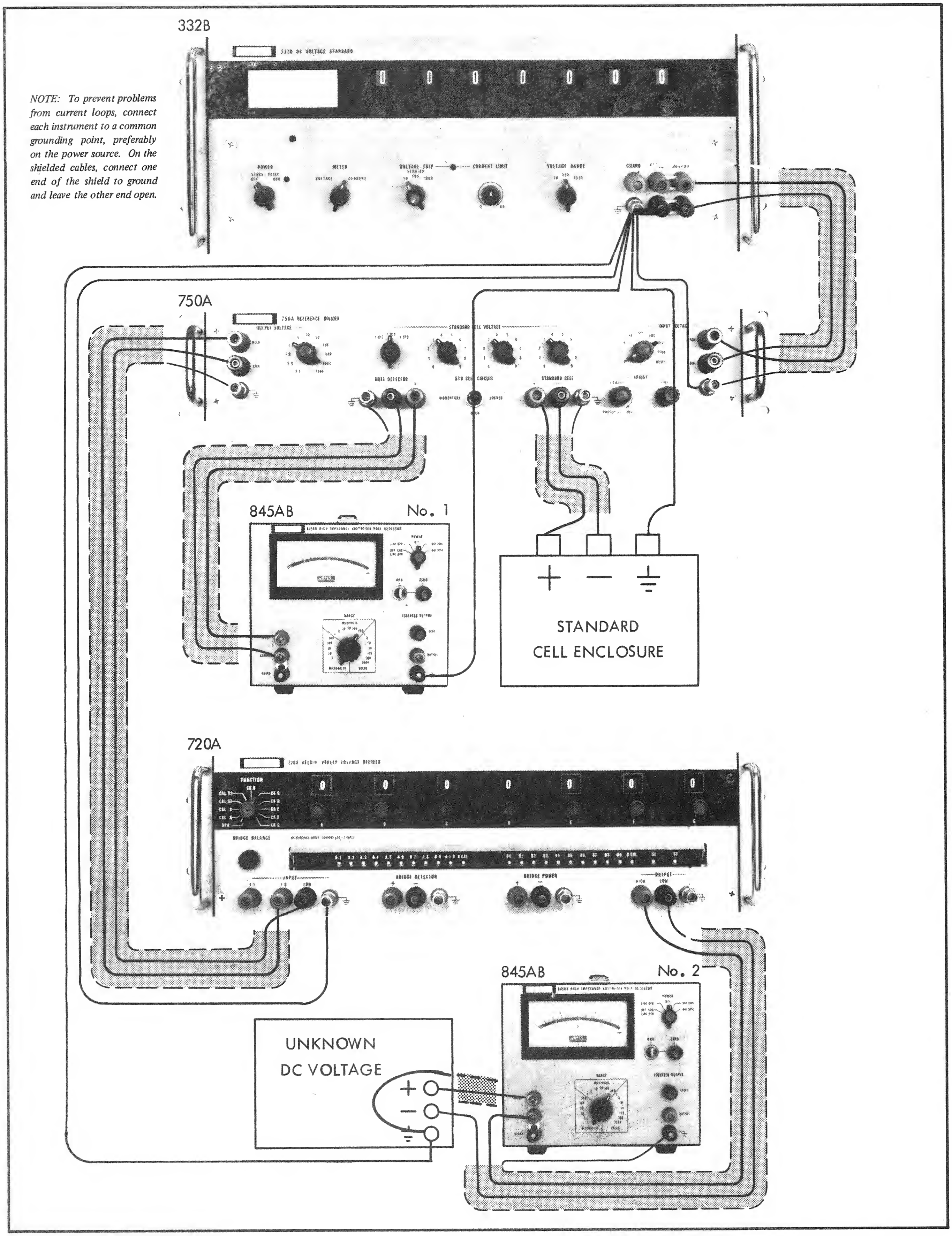


Figure 2-10. EQUIPMENT CONNECTIONS FOR VOLTAGE MEASUREMENTS (Sheet 1 of 2)

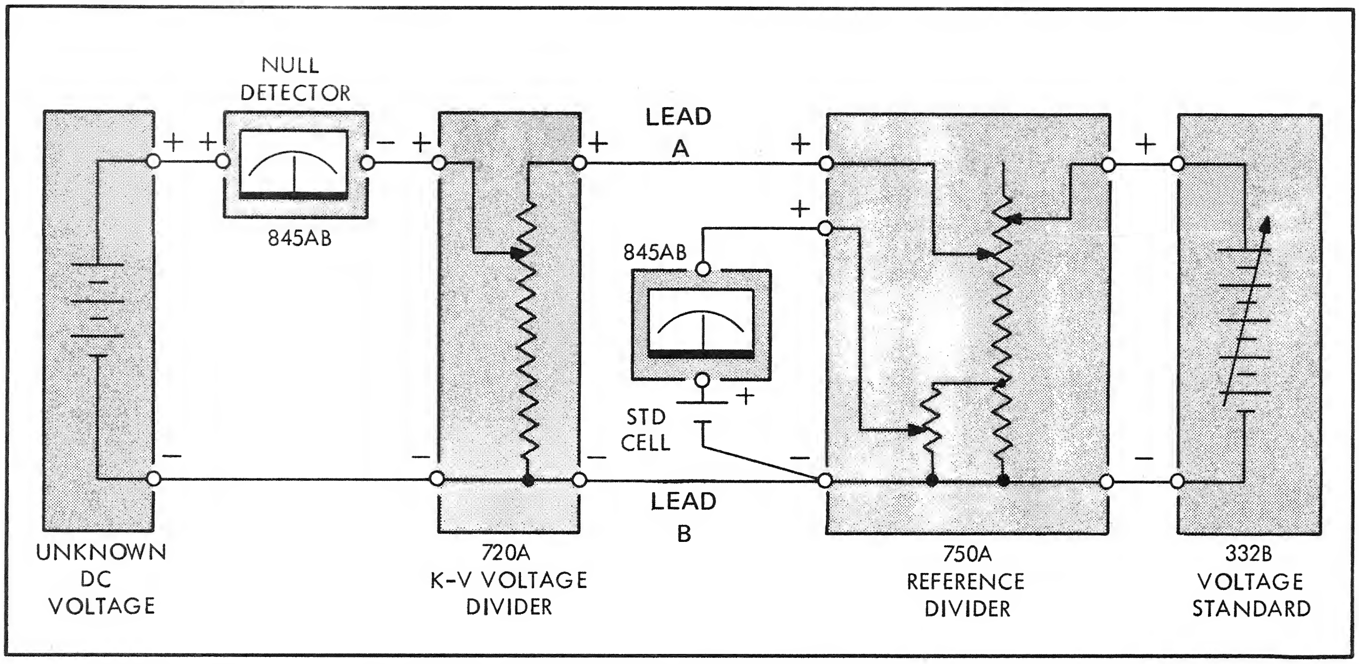


Figure 2-10. EQUIPMENT CONNECTIONS FOR VOLTAGE MEASUREMENTS (Sheet 2 of 2)

2-39. Measuring Unknown Resistance

2-40. The Model 720A may be used in a setup including a null detector, a power supply, and a standard resistor, to measure an unknown resistance with a high degree of accuracy. Typical associated equipment for this application is listed in Figure 2-13. The unknown resistance and the standard resistance should be in the same order of magnitude for the best accuracy.

2-41. To measure an unknown resistance, connect the equipment as shown in Figure 2-14 using shielded leads. Apply the positive lead from the dc voltage source to the 1.0 INPUT terminal of the Model 720A. Proceed as follows:

> P_1, P_2, P_3, and P_4 = decimal ratio set on the readout dials of the Model 720A at points P_1, P_2, P_3, and P_4 respectively.

If Rx + R std is greater than 100 ohms, the use of a lead compensator is desirable. If a lead compensator is used, P_1 can be made equal to 1.0000000 and P_4 can be made equal to .0000000.

$$\frac{Rx}{R\ std} = \frac{1 - P_2}{P_3}$$

If lead resistance between the resistors is made insignificant in addition to using a lead compensator, then $P_2 = P_3$ and the equation may be further simplified to:

$$\frac{Rx}{R\ std} = \frac{1}{P} - 1$$

a. Set the dc voltage source to the desired test voltage.

CAUTION!

Do not exceed the current rating of the standard resistor.

b. Set the readout dials of the Model 720A to zero.

c. Connect the null detector lead to point P_1 and adjust the readout dials of the Model 720A to obtain a null indication. Record the dial reading.

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.

Figure 2-11. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN VOLTAGES

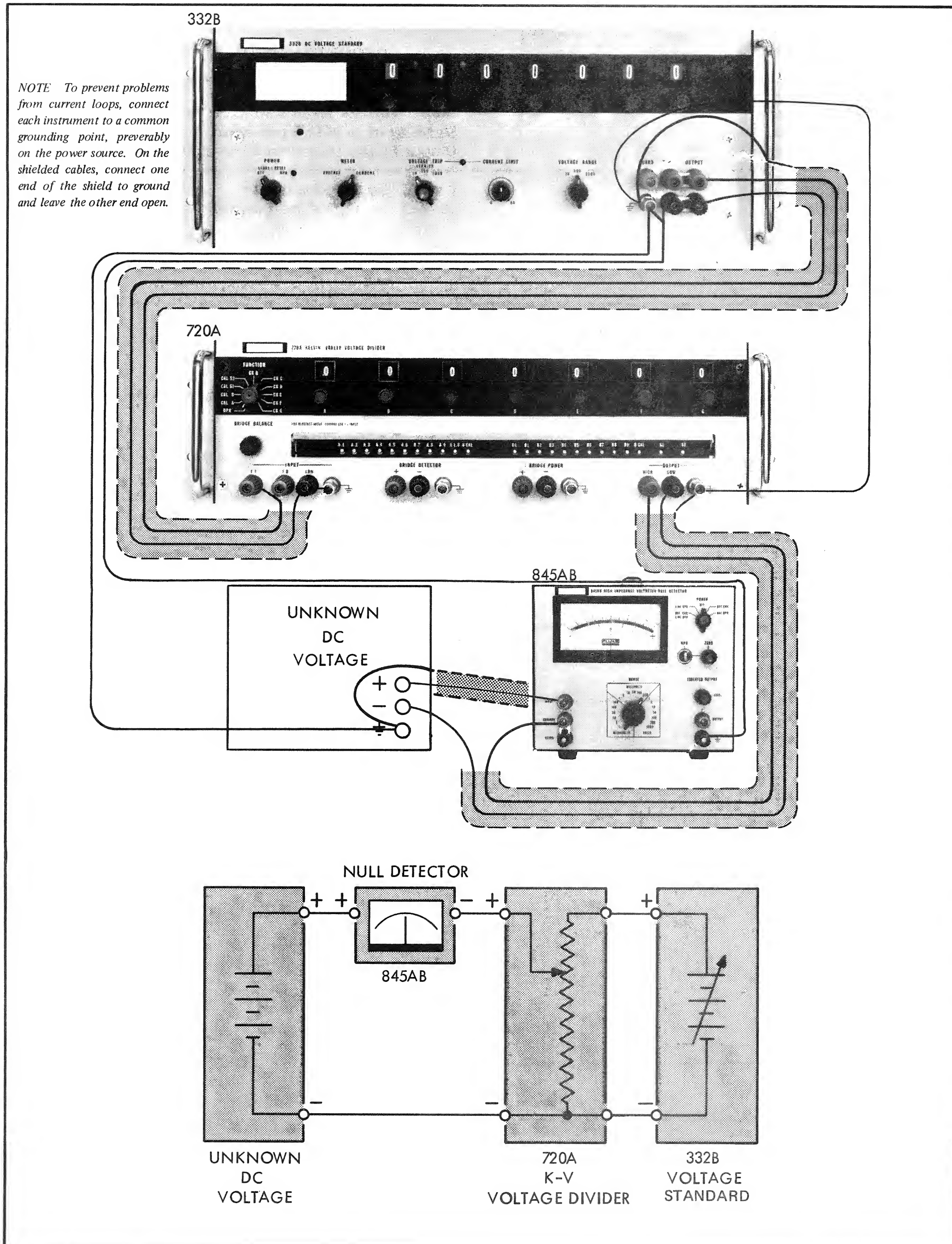


Figure 2-12. EQUIPMENT CONNECTIONS FOR SIMPLIFIED METHOD OF VOLTAGE MEASUREMENT

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Standard resistor.	

Figure 2-13. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN RESISTANCE RATIOS

d. Move the null detector lead to point P_2, adjust the readout dials to obtain a null, and record the dial reading.

e. Move the null detector lead to point P_3, adjust the readout dials to obtain a null, and record the reading.

f. Move the null detector lead to point P_4, adjust the dials to obtain a null, and record the dial reading.

g. Calculate the unknown resistance from the following equation.

$$\frac{Rx}{R\ std} = \frac{P_1 - P_2}{P_3 - P_4}$$

where:

Rx = unknown resistance
R std = standard resistance

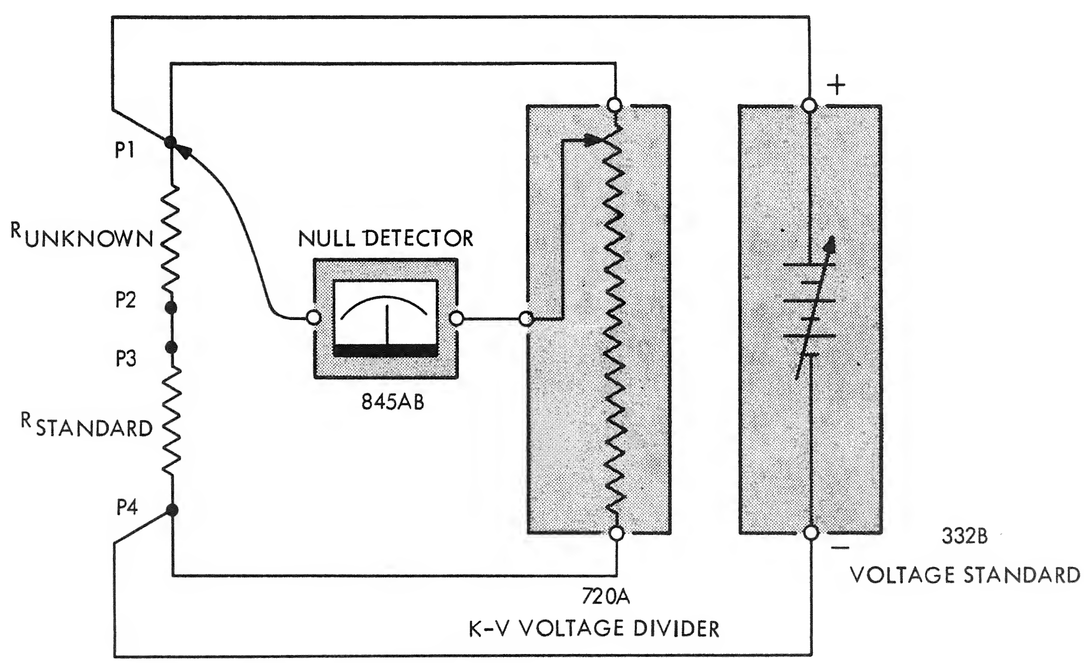


Figure 2-14. EQUIPMENT CONNECTIONS FOR DETERMINING AN UNKNOWN RESISTANCE VALUE (Sheet 1 of 2)

NOTE: To prevent problems from current loops, connect each instrument to a common grounding point, preferably on the power source. On the shielded cables, connect one end of the shield to ground and leave the other end open.

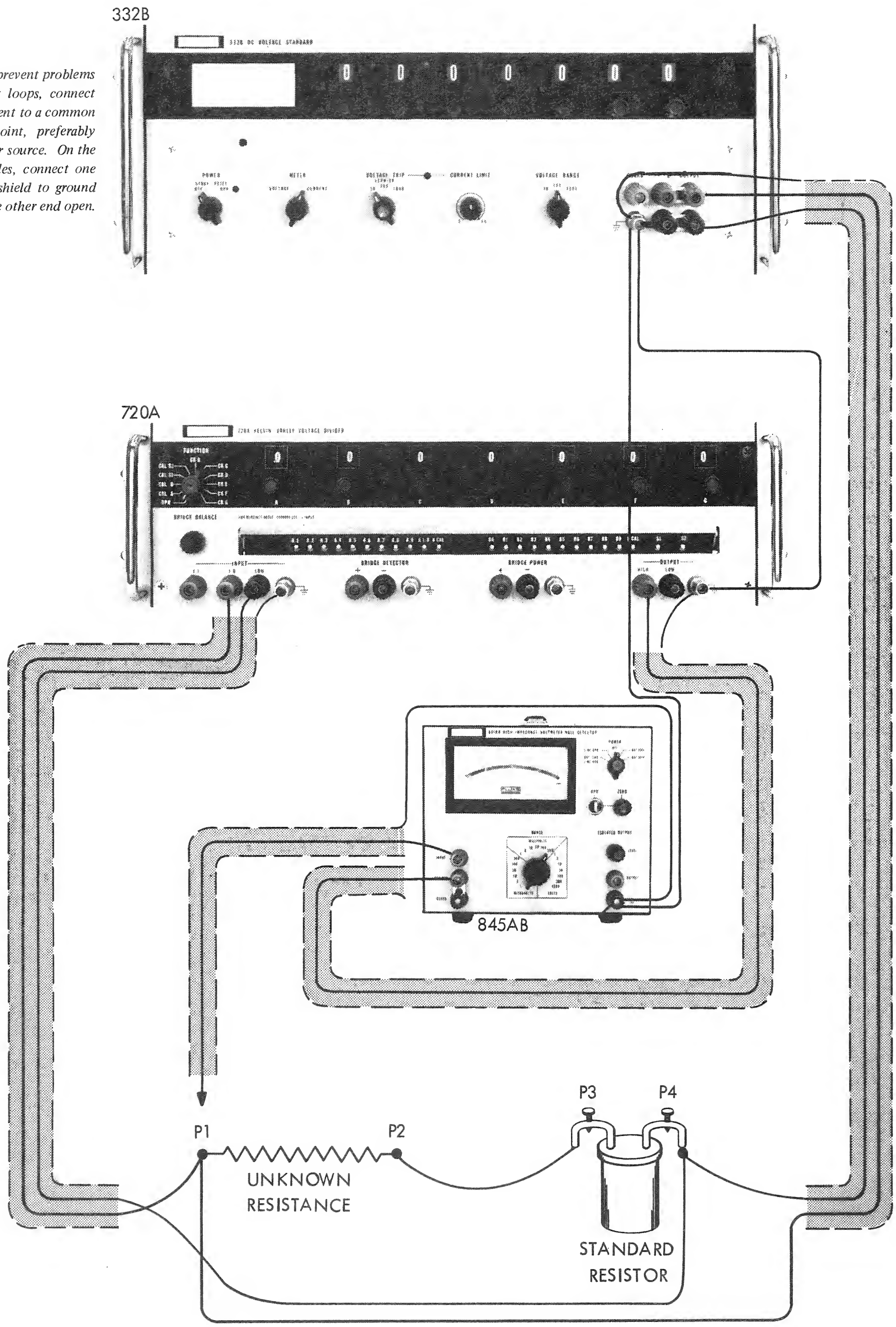


Figure 2-14. EQUIPMENT CONNECTIONS FOR DETERMINING AN UNKNOWN RESISTANCE VALUE (Sheet 2 of 2)

Section 3

Theory of Operation

3-1. INTRODUCTION

3-2. The Kelvin-Varley divider is a resistive circuit used primarily as a ratio standard. It is capable of dividing the input voltage with high resolution, usually to six or seven decimal places, and with high accuracy, usually a few parts per million.

3-3. THE BASIC CIRCUIT

3-4. Figure 3-1 is a simplified schematic diagram of a basic Kelvin-Varley divider. This simplified divider is capable of dividing the input voltage into 10,000 parts. It consists of four decades or resistive dividers each of which divides its input voltage into 10 equal parts ($10^4 = 10,000$).

3-5. For a decade to divide the voltage across it into 10 equal parts it must consist of 10 equal resistances. Placing the resistance of succeeding decade in parallel with a portion of the resistance of a decade, reduces the effective resistance of that portion. Referring to Figure 3-1, notice that the shunted resistance in the first decade is 20 kilohms and that each of the other steps is 10 kilohms. The 20 kilohms in the first decade is shunted by the 20 kilohms total effective resistance of the second decade resulting in a total effective resistance of 10 kilohms for that step. Thus all steps are kept equal. Each step of the second decade is two kilohms. The four kilohms spanned by the switch contacts is shunted by the four kilohms effective resistance of the third decade. Similarly 800 ohms of the third decade is shunted by the 800 ohms total resistance of the fourth decade.

3-6. CIRCUIT REFINEMENTS

3-7. Although the simplified Kelvin-Varley divider shown in Figure 3-1 shows all of the essential details of the basic circuit, a number of common design refinements should be mentioned. The latter decades may employ step resistors which are all of the same value and a shunt across the entire decade to reduce the effective decade resistance to the proper value. In Figure 3-1, this could be accomplished by using 400 ohm resistors in the fourth decade with a 1000 ohm shunt across the decade to reduce the effective resistance of the decade to 800 ohms. This avoids the necessity of using resistors of very small value in the latter decades. Usually each step of at least the first decade will consist of two equal resistors matched for equal but opposite temperature coefficients. This matching tends to produce a zero temperature coefficient for each step and for the entire decade, which reduces the nonlinearity caused by uneven temperature when power is applied. Some Kelvin-Varley dividers have adjustable trimmer resistors in the first, or even the second and third decades to permit compensation for drift and changes of ambient temperature. Overranging capability is provided in some circuits by adding an additional step of resistance and a 1.1 input terminal at the upper end of the first decade. In some dividers a small series resistance is added between the lower end of the divider string and the low input terminal to compensate for contact and wiring resistance bringing the low output voltage at zero setting to the same value as the low input voltage. Although these refinements improve the capability of the circuit, it operates in the same manner with them as without them.

3-8. THE MODEL 720A

3-9. The Model 720A is a seven-dial Kelvin-Varley divider with overranging and adjustable trimmers in the first three decades. The low output is compensated by a small resistance in series with the low input terminal. The input resistance (total effective resistance of the first decade is 110 kilohms at the 1.1 input terminal or 100 kilohms at the 1.0 input terminal. Resistors of equal value and fixed decade shunts are used in the last four decades to avoid using very small resistance values.

3-10. Design characteristics of the Model 720A which are not commonly found in Kelvin-Varley dividers include adjustable shunts in the first three decades, a built-in Wheatstone bridge, and switching to permit linearity adjustment (self-calibration) from the front panel. In addition, internal switching provides access to the second through the seventh decades so the linearity of any decade may be checked against a 10-step divider from the front panel.

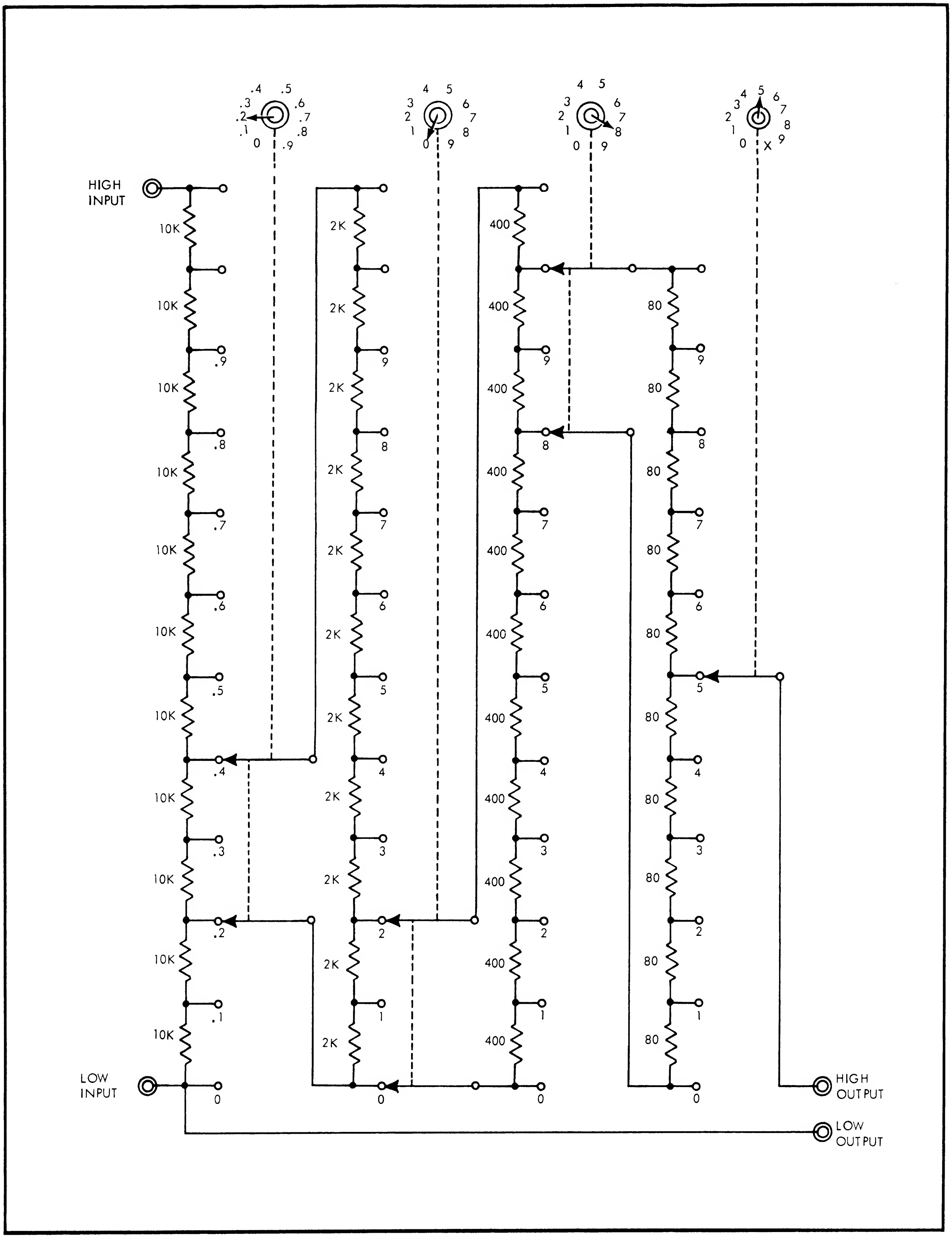


Figure 3-1. SIMPLIFIED SCHEMATIC DIAGRAM OF BASIC KELVIN-VARLEY DIVIDER CIRCUIT

Section 4
Maintenance

4-1. INTRODUCTION

4-2. This section contains the instructions and information required for maintenance of the Model 720A Kelvin–Varley Divider. Instructions are included for preventive maintenance, testing and repair of the instrument. If repair is beyond the capability of the user, it is recommended that the instrument be returned to the manufacturer. All maintenance procedures except the replacement of factory selected resistors and resistors housed in the oil tank are within the capability of a skilled technician if the listed test equipment is available.

4-3. The ratio accuracy of 0.1 ppm of the Model 720A is guaranteed for one year after shipment from the factory provided the instrument is regularly self-calibrated in accordance with paragraph 2-24 and is operated in the same environment in which it is self-calibrated. The instrument also must meet the requirements of the Leakage Resistance Test, paragraph 4-8. In the self-calibration procedure, all resistors on the A and B decades are adjusted to be equal to each other by substituting each in turn into the self-contained resistance bridge. The Linearity Test given in paragraph 4-14 should be performed once each year to verify instrument performance. If testing and calibration are beyond the capability of the user, these services may be obtained from a commercial calibration laboratory or from the manufacturer.

4-4. TEST EQUIPMENT REQUIRED FOR MAINTENANCE

4-5. The test equipment required for maintenance is listed in Figure 4-1. Equivalent or similar units may be substituted for those listed providing they have the required specifications listed in the figure.

4-6. PREVENTIVE MAINTENANCE

4-7. Preventive maintenance of the Model 720A consists of leakage resistance testing, cleaning, switch contact lubrication, and linearity testing. The frequency with which preventive maintenance procedures should be scheduled depends upon the user's requirements and the environment of the instrument. In an air conditioned standards laboratory, there will be little contamination of surfaces within this instrument and therefore testing and cleaning will seldom be required. In a contaminated atmosphere, frequent testing and cleaning may be required to maintain the accuracy of the instrument.

4-8. Leakage Resistance Tests

4-9. The need for cleaning can be determined without removing the cover from the Model 720A by performing

RECOMMENDED EQUIPMENT	SPECIFICATIONS REQUIRED
DC Voltage Source John Fluke Mfg. Co. Model 332B or Model 412B	Source of 0 to 1100 vdc. Accuracy at least 0.25% Stability at least 0.005% per hour.
DC Null Detector John Fluke Mfg. Co. Model 845AB	Sensitivity at least 10 microvolts full scale. 10 Megohm input Resistance.
Lead Compensator John Fluke Mfg. Co. Model 721A	Resolution of 0.1 milliohm. Ratio capability of 110:1
Standard Divider John Fluke Mfg. Co. Model 720A	Ratio accuracy of 0.1 ppm of input.
Standard Divider (11 Steps)	Ratio accuracy of 0.05 ppm of input
Decade Resistance Standard Electro Scientific Industries Model RS925A	4007.6 ohms, 10,000 ohms Accuracy of ±20 ppm

Figure 4-1. TEST EQUIPMENT REQUIRED FOR MAINTENANCE

the simple leakage resistance test described in this paragraph. This test should also be performed after cleaning to assure that all contamination has been removed. To measure leakage resistance, proceed as follows:

a. Place the Model 720A on a sheet of dielectric.

b. Use teflon insulated wire to connect the Model 720A, a 1000-volt source (Model 332B), and a null detector (Model 845AB) as shown in Figure 4-2.

c. Connect a shunt resistor across the input of the null-detector to bring its input resistance to one megohm on the one millivolt range. The value required for the Model 845AB is 1.1 megohms.

d. Turn on the 1000-volt supply and read the null detector. An indication of 1 millivolt corresponds to leakage resistance of 10^{12} ohms. If the indication is more than 1 millivolt, the leakage resistance is too low and corrective measures must be taken. If repeated cleaning fails to correct the problem, troubleshooting must be undertaken.

4-10. CLEANING

4-11. When the Model 720A is properly cared for and kept in a controlled atmosphere, cleaning will seldom be required. However, any contamination, particularly oil, in the instrument can contribute to reduced leakage resistance which will impair accuracy. Special care has been taken in the design and manufacture of the instrument to prevent leakage. The voltage dial switches are supported by Lexan spacers, and the circuit board is coated with a moisture sealant and isolated from the chassis by polyethelene grommets. These insulators and the switches can be contaminated easily by handling or by airborne contaminants. Dust may be removed with dry oil-free air at a pressure of 15 pounds per square inch or less. To remove oil, place the instrument on its side, place paper towels under it and spray with denatured anhydrous ethyl alcohol, Crown SPRA-TOOL No. 8011 or equivalent. When dry, perform switch contact lubrication, paragraph 4-12. After cleaning and drying, the leakage resistance test should be performed to assure that the excessive leakage has been corrected.

4-12. Switch Contact Lubrication

4-13. Corrosion of switch contacts can cause high contact resistance in one or more positions resulting in an impairment of linearity. If evidence of this condition is present and exercising the switch fails to correct it, the switch contact should be lubricated with a special purpose switch lubricant. The product recommended for this purpose is Rykon lubricant No. 2 EP (American Oil Co.) mixed with Tuluol. It should be carefully applied in a very thin film with a camel's hair brush.

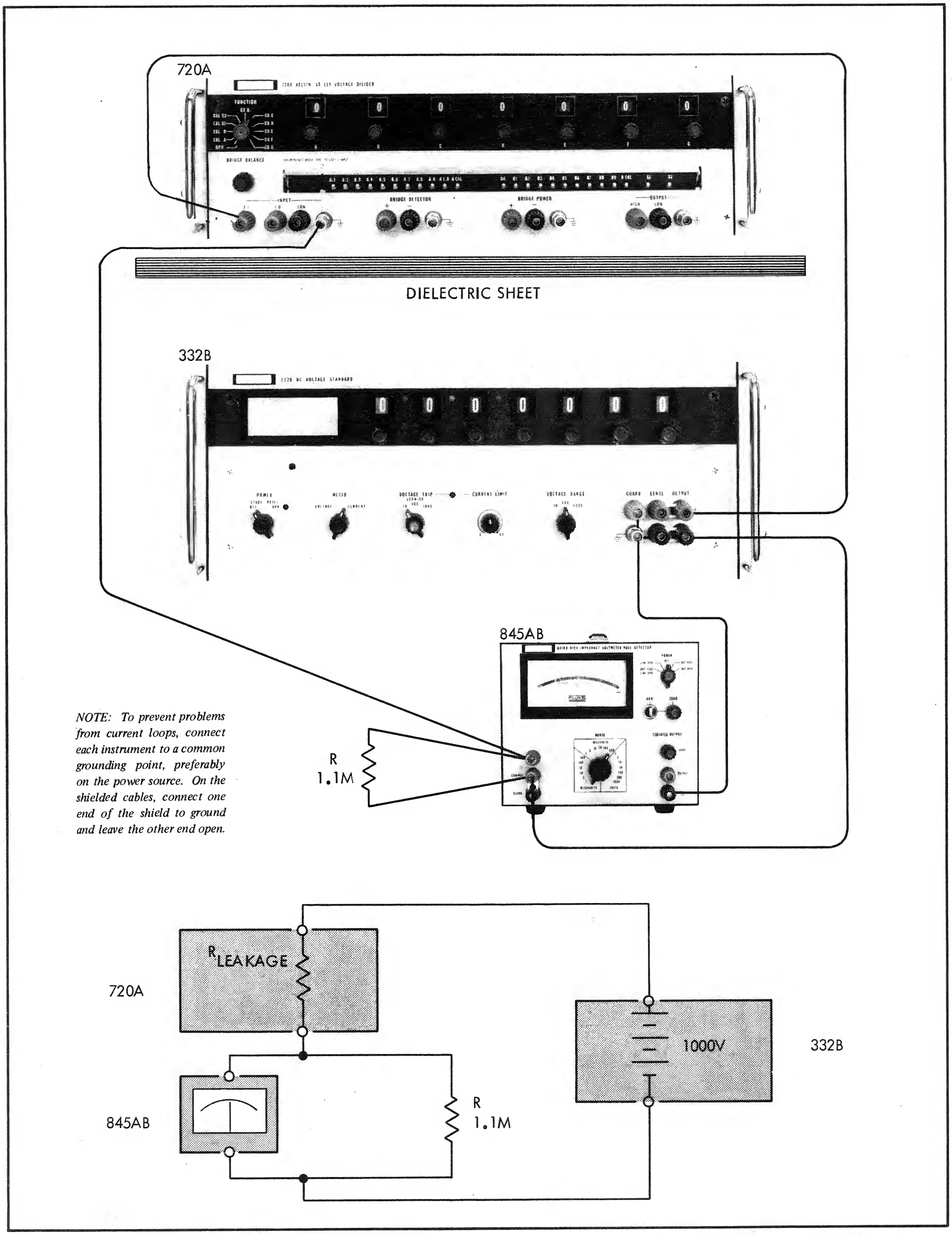
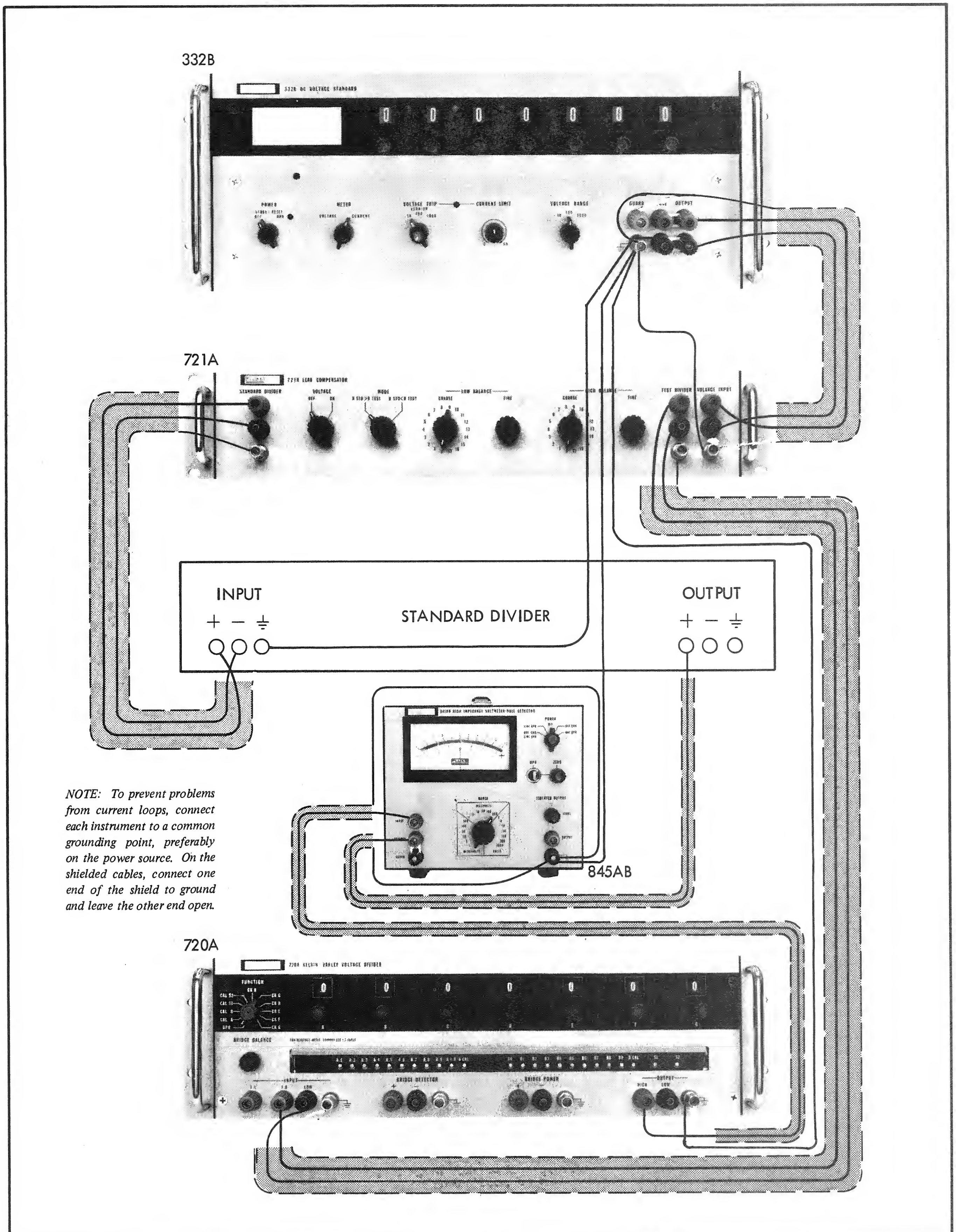


Figure 4-2. EQUIPMENT CONNECTIONS FOR LEAKAGE RESISTANCE TEST



NOTE: To prevent problems from current loops, connect each instrument to a common grounding point, preferably on the power source. On the shielded cables, connect one end of the shield to ground and leave the other end open.

Figure 4-3. EQUIPMENT CONNECTIONS FOR LINEARITY COMPARISON TEST

CAUTION!

Great care should be used to avoid excessive use of contact lubricant on the switches of the Model 720A. The contacts should not be lubricated unless there is evidence of irregular operation.

Before applying the lubricant, clean the switch following the instructions in paragraph 4-10. Only a minute amount of lubricating fluid should be applied. After application, exercise the switch by rotating it through all positions several times.

4-14. Linearity Testing

4-15. The design of the 720A Voltage Divider is such that if the instrument is self-calibrated, if the leakage resistance is low, and if the switch contacts display repeatable contact resistance, the divider will meet its linearity specifications. Because of the extremely tight over-all specification (0.1 PPM of input) very few laboratories will have both the necessary equipment and the required technical skills to prove this. The following linearity test using a second Model 720A as a standard is therefore intended only to indicate gross errors (0.2 PPM of input) in the first decade and to prove specification on the lower decades. The customer who hopes to prove more than this is referred to the following articles and papers:

1. Andrew F. Dunn, "Calibration of a Kelvin-Varley Voltage Divider," National Research Council Report No. 7863.

2. M. L. Morgan and J. C. Riley, "Calibration of a Kelvin-Varley Standard Divider," IRE Trans. on Instrumentation, vol. 1-9, pp 237-243; Sept. 1960.

4-16. To compare divider linearity, connect the equipment as shown in Figure 4-3 and proceed as follows:

NOTE!

Figure 4-4 is a schematic diagram of the test set-up obtained by interconnecting the equipment as shown in Figure 4-3.

a. Self-calibrate the Model 720A. (See paragraph 2-24 in Section II).

b. Set both dividers to zero.

c. Set the voltage source to the desired test voltage, turn on all equipment and allow it to warm up until it reaches temperature equilibrium.

d. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

e. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

f. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may

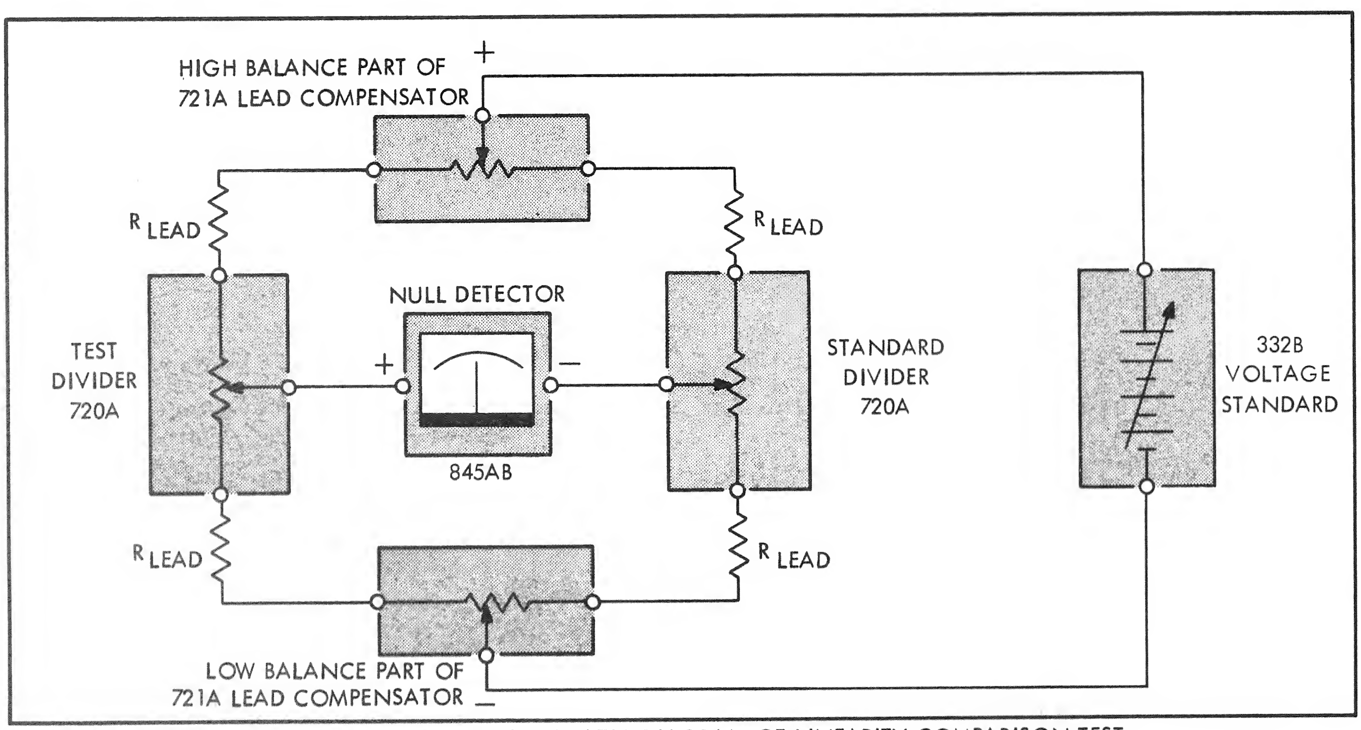


Figure 4-4. SIMPLIFIED SCHEMATIC DIAGRAM OF LINEARITY COMPARISON TEST

be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on from saturating the null detector amplifier.

g. Set both dividers to full scale and adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

h. Set both dividers to zero and re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

i. Set the null detector to the desired sensitivity.

j. Set both dividers to the first comparison point and adjust the standard divider for a near zero indication on the null detector. The dial settings of the two dividers plus the null detector reading shall agree within a tolerance of 0.2 PPM. This criterion is applicable for input voltages of 100 volts or less.

k. Continue to compare each setting of each decade until the comparison is complete. The following dial setting combinations should be checked on each decade.

0 all zeros	________
1 all zeros	1 (dial 09 and all 9s except X in last)
2 all zeros	2 (dial 19 and all 9s except X in last)
3 all zeros	3 (dial 29 and all 9s except X in last)
4 all zeros	4 (dial 39 and all 9s except X in last)
5 all zeros	5 (dial 49 and all 9s except X in last)
6 all zeros	6 (dial 59 and all 9s except X in last)
7 all zeros	7 (dial 69 and all 9s except X in last)
8 all zeros	8 (dial 79 and all 9s except X in last)
9 all zeros	9 (dial 89 and all 9s except X in last)
1.0 all zeros	10 (dial 99 and all 9s except X in last)
________	1.1 (dial 1.09 and all 9s except X in last)

4-17. Decade Linearity Testing

4-18. The CK B through CK G positions of the FUNCTION switch are provided to permit access to the individual decades of the Model 720A under test so that each may be checked against the first decade of the standard divider. To test the linearity of each decade individually, proceed as follows:

a. Change the test setup to that shown in Figure 4-5.

NOTE!

Figure 4-6 is a schematic diagram of the test setup obtained by interconnecting the equipment as shown in Figure 4-5.

b. Turn the FUNCTION switch to CK B.

c. Set the standard divider to zero.

d. Set the divider under test to <u>1.0</u> 000000.

e. Set the voltage source to the desired test voltage.

CAUTION!

Do not exceed the maximum test voltages listed in Figures 4-7 through 4-12.

f. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

g. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

h. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on, from saturating the null detector amplifier.

i. Set the standard divider to full scale.

j. Set the divider under test to <u>1.0</u> 99999X.

k. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

l. Set the divider under test back to <u>1.0</u> 000000 and set the standard divider back to zero.

m. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

n. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-7. The null detector indications must be

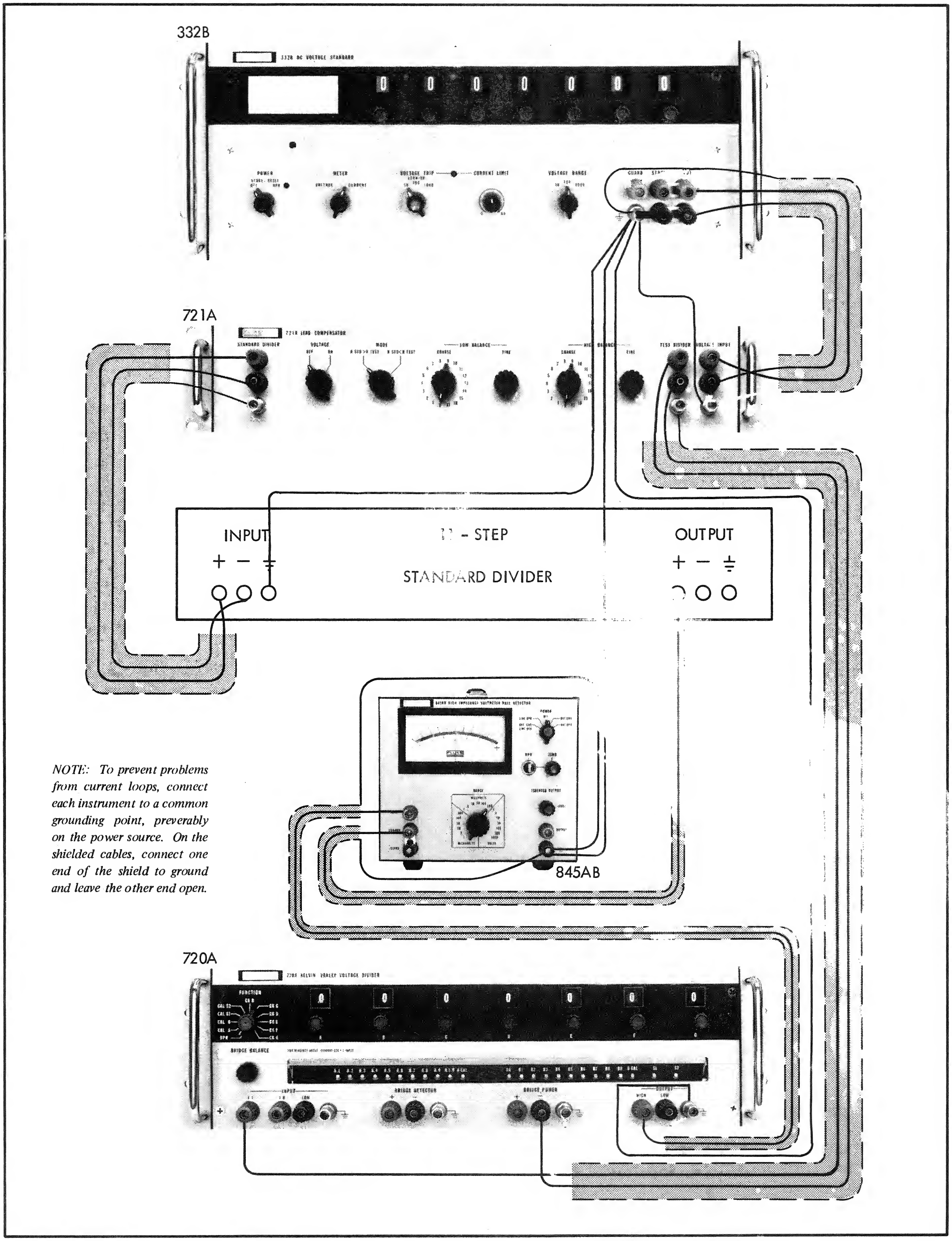


Figure 4-5. EQUIPMENT CONNECTIONS FOR DECADE LINEARITY TEST

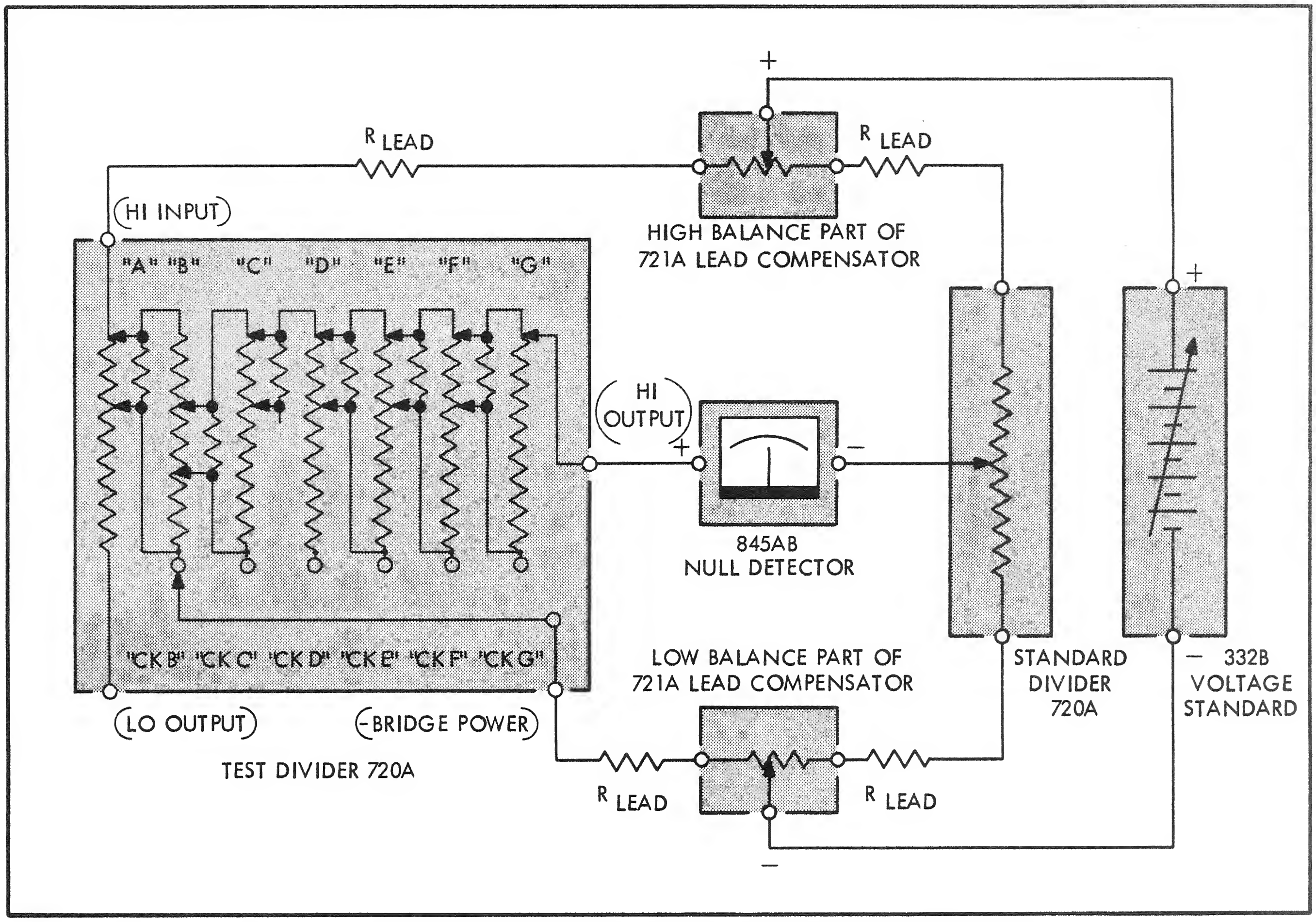


Figure 4-6. SIMPLIFIED SCHEMATIC DIAGRAM OF DECADE LINEARITY TEST

within the limits listed in the Permissible Deviation column.

NOTE!

An indication beyond these limits is a symptom of trouble within the instrument. Refer to the troubleshooting instructions to determine the nature of the fault.

o. Set the voltage source to the desired voltage for testing the "C" decade.

p. Turn the FUNCTION switch to CK C.

q. Set the standard divider to zero.

r. Set the divider under test to <u>1. 0</u> 900000.

s. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

t. Adjust the LOW BALANCE CONTROLS of the lead compensator to obtain a zero indication on the null detector.

u. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

v. Set the standard divider to full scale.

w. Set the divider under test to <u>1. 0</u> 99999X.

x. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

y. Set the divider under test back to 1. 0 900000 and set the standard divider back to zero.

z. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

aa. Set the null detector for the desired sensitivity and make the linearity measurements listed in Figure 4-8.

ab. Set the voltage source to the desired test voltage for testing "D" Decade.

ac. Turn the FUNCTION switch to CK D.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "B" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 000000	0	100V
.1	1.0 100000	0.38	
.2	1.0 200000	0.45	
.3	1.0 300000	0.50	
.4	1.0 400000	0.54	
.5	1.0 500000	0.57	
.6	1.0 600000	0.60	
.7	1.0 700000	0.63	
.8	1.0 800000	0.65	
.9	1.0 900000	0.67	
.999999X	1.0 99999X	0	
.9	1.0 89999X	0.67	
.8	1.0 79999X	0.65	
.7	1.0 69999X	0.63	
.6	1.0 59999X	0.60	
.5	1.0 49999X	0.57	
.4	1.0 39999X	0.54	
.3	1.0 29999X	0.50	
.2	1.0 19999X	0.45	
.1	1.0 09999X	0.38	

Figure 4-7. "B" DECADE LINEARITY TEST

ad. Set the standard divider to zero.

ae. Set the divider under test to 1.0 990000.

af. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

ag. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

ah. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

ai. Set the standard divider to full scale.

aj. Set the divider under test to 1.0 99999X.

ak. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

al. Set the divider under test back to 1.0 990000 and set the standard divider back to zero.

am. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

an. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-9. The null detector indications must be within the limits listed in the "permissible deviation" column.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "C" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 900000	0	100V
.1	1.0 910000	1.4	
.2	1.0 920000	1.7	
.3	1.0 930000	1.9	
.4	1.0 940000	2.1	
.5	1.0 950000	2.3	
.6	1.0 960000	2.4	
.7	1.0 970000	2.5	
.8	1.0 980000	2.7	
.9	1.0 990000	2.8	
.999999X	1.0 99999X	0	
.9	1.0 98999X	2.8	
.8	1.0 97999X	2.7	
.7	1.0 96999X	2.5	
.6	1.0 95999X	2.4	
.5	1.0 94999X	2.3	
.4	1.0 93999X	2.1	
.3	1.0 92999X	1.9	
.2	1.0 91999X	1.7	
.1	1.0 90999X	1.4	

Figure 4-8. "C" DECADE LINEARITY TEST

ao. Turn the FUNCTION switch to CK E.

ap. Set the standard divider to zero.

aq. Set the divider under test to 1.0 999000.

ar. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

as. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

at. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

au. Set the standard divider to full scale.

av. Set the divider under test to 1.0 99999X.

aw. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

ax. Set the divider under test back to 1.0 999000 and set the standard divider back to zero.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "D" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 990000	0	10V
.1	1.0 991000	6.0	
.2	1.0 992000	7.5	
.3	1.0 993000	8.6	
.4	1.0 994000	9.5	
.5	1.0 995000	10.2	
.6	1.0 996000	10.8	
.7	1.0 997000	11.4	
.8	1.0 998000	12.0	
.9	1.0 999000	12.5	
.999999X	1.0 99999X	0	
.9	1.0 99899X	12.5	
.8	1.0 99799X	12.0	
.7	1.0 99699X	11.4	
.6	1.0 99599X	10.8	
.5	1.0 99499X	10.2	
.4	1.0 99399X	9.5	
.3	1.0 99299X	8.6	
.2	1.0 99199X	7.5	
.1	1.0 99099X	6.0	

Figure 4-9. "D" DECADE LINEARITY TEST

ay. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

az. Set the null detector for the desired sensitivity and make the linearity measurement given in Figure 4-10. The null detector indications must be within the limits listed in the "permissible deviation" column.

ba. Turn the FUNCTION switch to CK F.

bb. Set the standard divider to zero.

bc. Set the divider under test 1.0 999900.

bd. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

be. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

bf. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

bg. Set the standard divider to full scale.

bh. Set the divider under test to 1.0 99999X.

bi. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "E" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999000	0	10V
.1	1.0 999100	28	
.2	1.0 999200	35	
.3	1.0 999300	40	
.4	1.0 999400	44	
.5	1.0 999500	47	
.6	1.0 999600	50	
.7	1.0 999700	53	
.8	1.0 999800	55	
.9	1.0 999900	57	
.999999X	1.0 999990	0	
.9	1.0 99989X	57	
.8	1.0 99979X	55	
.7	1.0 99969X	53	
.6	1.0 99959X	50	
.5	1.0 99949X	47	
.4	1.0 99939X	44	
.3	1.0 99929X	40	
.2	1.0 99919X	35	
.1	1.0 99909X	28	

Figure 4-10. "E" DECADE LINEARITY TEST

bj. Set the divider under test back to 1.0 999900 and set the standard divider back to zero.

bk. Re-adjust the LOW BALANCE FINE control if necessary to obtain zero indication on the null detector.

bl. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-11. The null detector indications must be within the limits listed in the "permissible deviation" column.

bm. Turn the FUNCTION switch to CK G.

bn. Set the standard divider to zero.

bo. Set the divider under test to 1.0 999990.

bp. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

bq. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

br. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

bs. Set the standard divider to full scale.

bt. Set the divider under test to 1.0 99999X.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "F" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999900	0	10V
.1	1.0 999910	130	
.2	1.0 999920	160	
.3	1.0 999930	180	
.4	1.0 999940	200	
.5	1.0 999950	220	
.6	1.0 999960	230	
.7	1.0 999970	240	
.8	1.0 999980	260	
.9	1.0 999990	270	
.999999X	1.0 99999X	0	
.9	1.0 99998X	270	
.8	1.0 99997X	260	
.7	1.0 99996X	240	
.6	1.0 99995X	230	
.5	1.0 99994X	220	
.4	1.0 99993X	200	
.3	1.0 99992X	180	
.2	1.0 99991X	160	
.1	1.0 99990X	130	

Figure 4-11. "F" DECADE LINEARITY TEST

bu. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

bv. Set the divider under test back to 1.0 999990 and set the standard divider back to zero.

bw. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

bx. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-12. The null detector indications must be within the limits listed in the "permissible deviation" column.

by. Disconnect the test equipment and return the FUNCTION switch to OPR position; the decade linearity tests are complete.

4-19. CALIBRATION

4-20. Calibration of the Model 720A consists of calibrating two standard resistance arms of the internal Wheatstone bridge and calibrating the first three decades. The bridge arms require calibration only if the BRIDGE BALANCE control has insufficient range to balance the bridge during divider calibration.

4-21. Divider Calibration

4-22. This procedure is used to adjust the linearity of the "A", "B" and "C" decades of the Model 720A so

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "G" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999990	0	10V
.1	1.0 999991	600	
.2	1.0 999992	750	
.3	1.0 999993	860	
.4	1.0 999994	950	
.5	1.0 999995	1020	
.6	1.0 999996	1080	
.7	1.0 999997	1140	
.8	1.0 999998	1200	
.9	1.0 999999	1250	
.999999X	1.0 99999X	0	

Figure 4-12. "G" DECADE LINEARITY TEST

that any readout setting is accurate within 0.1 ppm of input. This procedure consists of two parts, calibration of the "C" decade and the "S3" shunt, and calibration of the "A" and "B" decades, and their shunts. The latter is the self calibration procedure which is performed from the front panel.

4-23. To calibrate the "C" decade and "S3" shunt proceed as follows:

NOTE!

Insure the system has the correct connections and ground as shown in Figure 4-14.

a. Turn the FUNCTION switch to OPR, turn the internal FUNCTION switch to CAL C, exercise the "C" decade switch by turning it twice through all positions, and set the readout to .0000000.

b. Connect the voltage source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the common terminal.

d. Turn the B decade switch to the blank position and apply 10 volts from the voltage source.

e. Adjust the BRIDGE BALANCE control to obtain a null indication $\pm$10 microvolts.

NOTE!

If the null meter cannot be nulled using the Bridge Balance Control, perform the Bridge Calibration Procedure (paragraph 4-25).

f. Locate the C-0 trimmer (R1130) on the circuit board and sweep it slowly from stop to stop while observing the null detector. If the indication does not change smoothly, sweep it from stop to stop several times.

g. Set the null detector to the 30 microvolt range and adjust the C-0 trimmer to obtain an indication of 0 $\pm$10 microvolts.

h. Observe the null detector and tap the trimmer; the indication should remain within 10 microvolts of zero.

i. Use the following procedure to calibrate the "C" deck switch positions 1 through CAL:

1. Turn the "C" deck switch clockwise to the next position to be calibrated.

2. Observe the null detector and slowly sweep the trimmer corresponding to the switch position (C-1 through C CAL) from stop to stop. If the indication does not change smoothly, sweep the trimmer from stop to stop several times.

3. Observe the null detector and adjust the trimmer to obtain an indication of 0 ±10 microvolts.

4. Observe the null detector and tap the trimmer; the indication should stay within 10 microvolts of the zero.

5. Turn the "C" deck switch away from the position being calibrated, return it and observe the meter. The indication should be within 10 microvolts of zero

NOTE!

If the indication is not within 10 microvolts of zero, exercise the switch and repeat the procedure. If this fails, lubricate the switch as instructed in paragraph 4-12.

6. Proceed to the next position to be calibrated.

j. Return the "C" deck switch to the 0 position.

k. Turn the internal FUNCTION switch to the CAL S3 position.

l. Observe the null detector and slowly sweep the CAL S3 trimmer from stop to stop. If the indication does not change smoothly, sweep it from stop to stop several times.

m. Adjust the CAL S3 trimmer to obtain an indication of 0 ±10 microvolts.

n. Observe the null detector and tap the trimmer. The indication should stay within 10 microvolts of zero.

o. Turn the "C" decade switch away from the 0 positions and return it to zero.. The null detector indication should be within 10 microvolts of zero.

p. Return the internal FUNCTION switch to OPR; Calibration of the "C" decade and S3 shunt is complete.

4-24. To calibrate the "A" and "B" decades, perform the self-calibration procedure using the instructions given in paragraphs 2-24 and 2-25.

4-25. Bridge Calibration

NOTE!

The Bridge Calibration procedure is required only if a null could not be obtained during Divider Calibration with the BRIDGE BALANCE Control.

4-26. 10-KILOHM BRIDGE STANDARD. This procedure is used to adjust the total resistance of the bridge arm used for calibration of the "A" and "B" decades (self-calibration of the instrument) so the bridge can be balanced to measure a nominal 10,000 ohms. If the bridge can be balanced near the center of travel for the BRIDGE BALANCE during self-cal at CAL A - Zero positions the procedure following does not need to be performed. However, if during self-cal in the CAL A - Zero position (See paragraph 2-24) the bridge cannot be balanced using the BRIDGE BALANCE Control, perform the procedure below:

NOTE!

Insure the system has the correct connections and ground as shown in Figure 4-14.

a. Turn the FUNCTION switch to CAL A; turn the internal FUNCTION switch to OPR (Fig. 4-13) and set the readout to .0000000.

b. Connect a 20 volt DC source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the Common terminal.

Figure 4-13. INTERNAL FUNCTION SWITCH

d. Adjust the Bridge Balance control to the center of its travel range.

NOTE!

BRIDGE BALANCE is a concentric control with both a Fine and Coarse range on the same control knob.

e. Observe the null detector and sweep R203 on the bridge circuit board slowly from stop to stop. If the indication does not change smoothly, sweep R203 from stop to stop several times.

f. Adjust R203 to obtain an indication of 0 ±100 microvolts.

g. Select the one millivolt range on the null detector. Vary the Bridge Balance control while observing the null detector. When the electrical center is obtained, leave the BRIDGE BALANCE control at that position.

h. Re-adjust R203 to obtain an indication of 0 ± 100 microvolts

i. Calibration of the 10-kilohm bridge standard is complete.

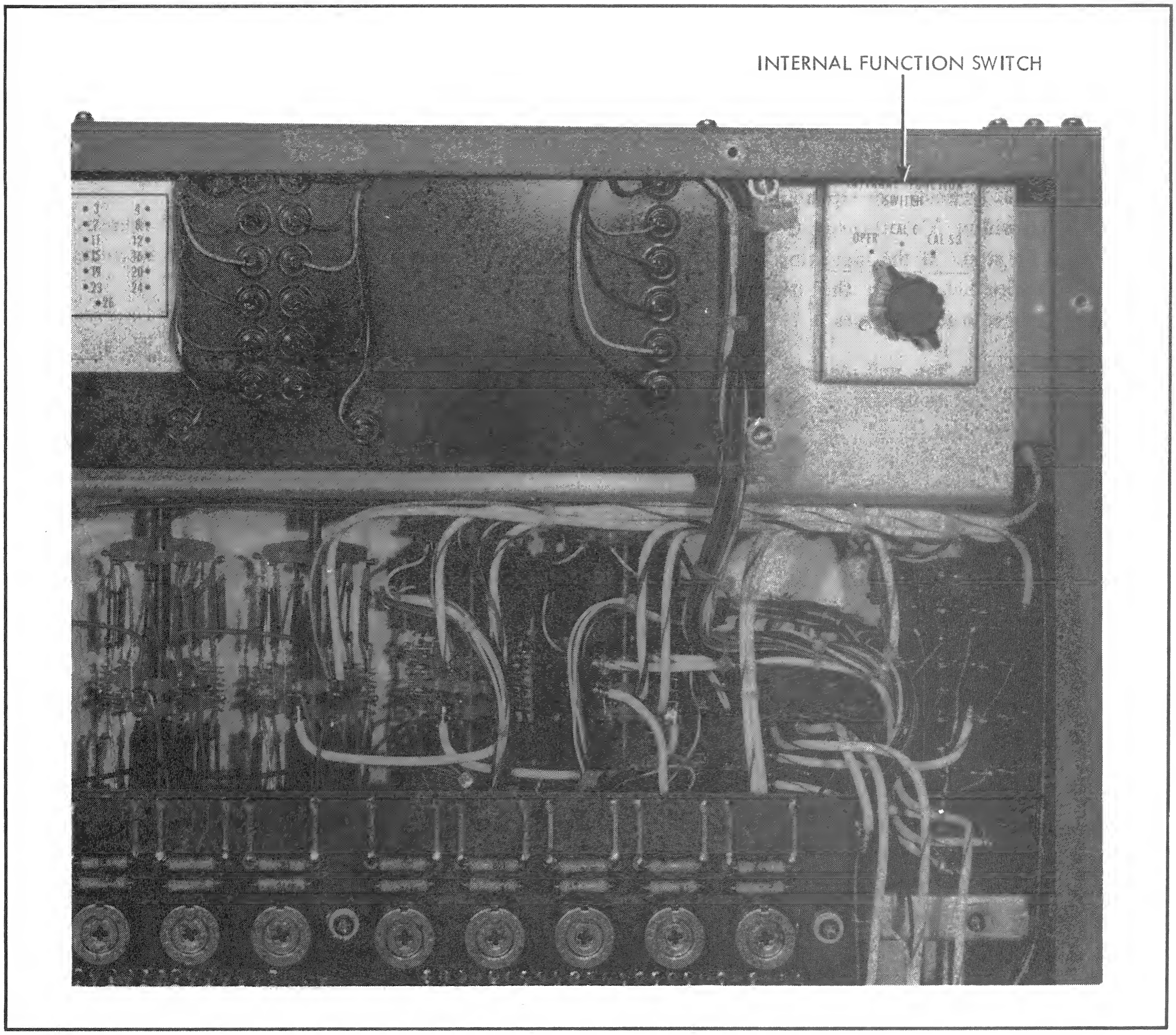


Figure 4-13. INTERNAL FUNCTION SWITCH

d. Adjust the Bridge Balance control to the center of its travel range.

NOTE!

BRIDGE BALANCE is a concentric control with both a Fine and Coarse range on the same control knob.

e. Observe the null detector and sweep R203 on the bridge circuit board slowly from stop to stop. If the indication does not change smoothly, sweep R203 from stop to stop several times.

f. Adjust R203 to obtain an indication of 0 ±100 microvolts.

g. Select the one millivolt range on the null detector. Vary the Bridge Balance control while observing the null detector. When the electrical center is obtained, leave the BRIDGE BALANCE control at that position.

h. Re-adjust R203 to obtain an indication of 0 ± 100 microvolts

i. Calibration of the 10-kilohm bridge standard is complete.

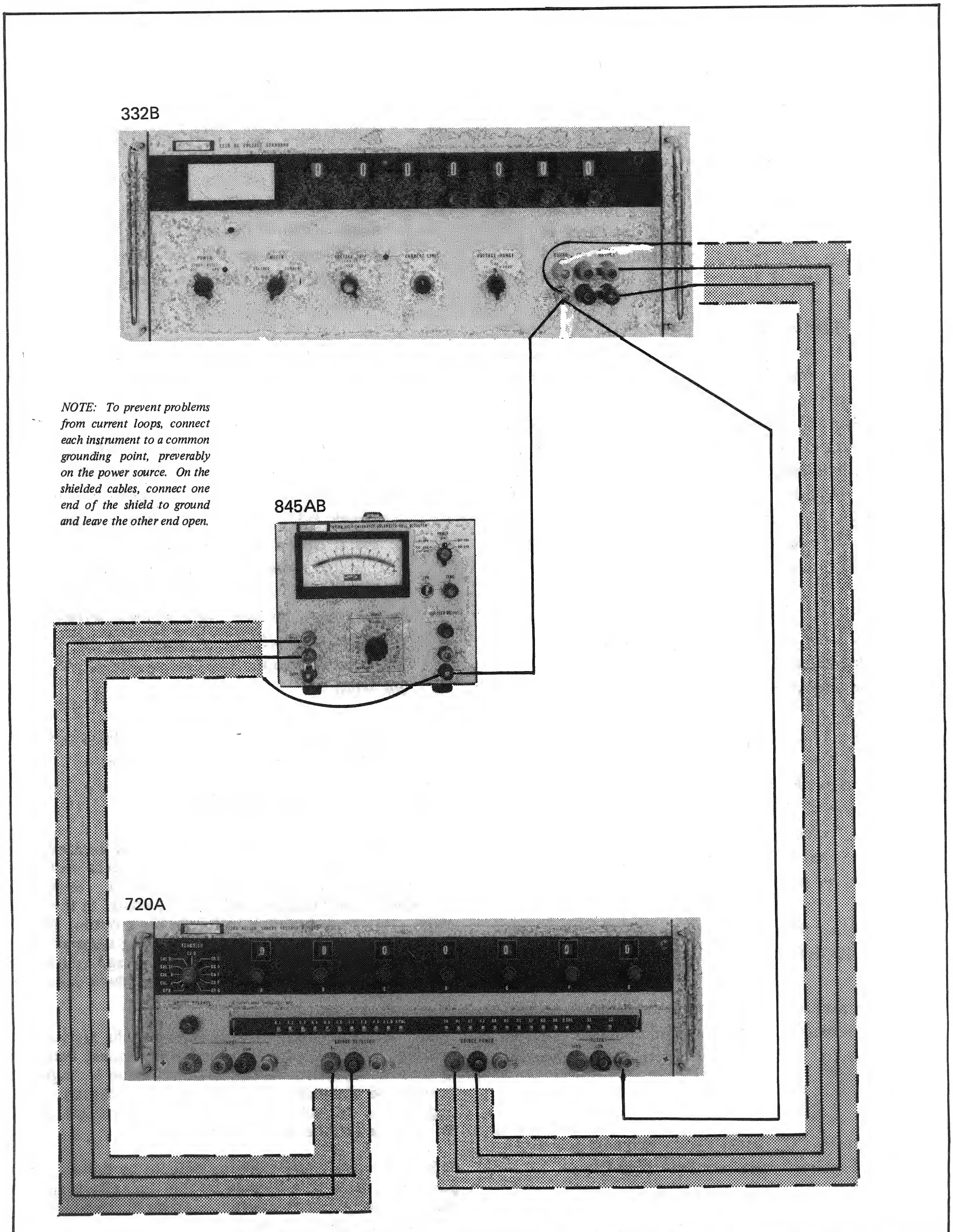


Figure 4-14. EQUIPMENT CONNECTIONS FOR SELF CALIBRATION.

NOTE!

The BRIDGE BALANCE control and R203 are now ready for the self-cal procedures for A and B decades in paragraph 2-24, assuming R312 and its associated trim resistors have not shifted excessively in value. If insufficient trim range remains at A.1, A.2, etc., the 720A should be returned to the factory for repair. Perform the C decade and S3 shunt check in paragraph 4-21 prior to performing the self-cal at A and B decades.

4-27. 4-KILOHM BRIDGE STANDARD. This procedure is used to adjust the total resistance of the bridge arm used for calibration of the third "C" decade so the bridge can be balanced to measure a nominal 4007.6 ohms. Calibration of the "C" decade consists of setting each step on the decade to a nominal 4007.6 ohms. If the bridge can be balanced with the BRIDGE BALANCE control on the front panel during self-cal in the CAL C - Zero position described in paragraph 4-21, this procedure does not need to be performed. To reset the range of the BRIDGE BALANCE, control for balance of the bridge, perform the following procedure:

a. Turn the FUNCTION switch to OPR, and turn the internal FUNCTION switch to CAL C, and set the readout to .0000000.

NOTE!

The internal FUNCTION switch, which is shown in Figure 4-13, is used only for calibration of the "C" decade and the S-3 shunt. It should not be confused with the FUNCTION switch located on the front panel.

b. Connect the voltage source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the common terminal.

d. Turn the "C" decade switch to the blank position and apply 10 volts from the voltage source.

e. Adjust BRIDGE BALANCE to the mid-position and adjust R1130 (Decade C-9) to mid position

f. Observing the Null Detector sweep R205 (Bridge Circuit Board) thru its range. If the null detector does not show a smooth change, sweep R205 through its range several times.

g. Adjust R205 for 0 ±50 microvolts on the Null Detector.

h. Place the Null Detector on the 300 microvolt range. Observe the range of the BRIDGE BALANCE control on the Null Detector and place the BRIDGE BALANCE control at the electrical center.

i. Adjust R1130 (Decade C-0) for 0 ±10 microvolts.

NOTE!

The BRIDGE BALANCE control, R205 and R1130 are now set to give a nominal 4007.6 ohm reference and the self-cal procedure in paragraph 4-21 will make the other positions of the C Decade the same value. If there is not enough range to trim the remaining positions of the C Decade to this nominal value repeat steps a through i with different settings for R205 and R1130. If calibration still is not possible, return the 720A to the factory for repair.

j. Disconnect the test equipment; calibration of the 4-kilohm bridge standard is complete.

4-28. TROUBLESHOOTING

4-29. Troubles in the Model 720A may be located most easily by performing the decade linearity test described in paragraph 4-15 and analyzing the results. Reference to the schematic diagram will greatly assist in the analysis. Before attempting to locate the trouble, the instrument should first be cleaned following the procedure described in paragraph 4-10 and the leakage resistance should be measured following the procedure described in paragraph 4-8.

4-30. Because of the passive nature of the instrument, troubles will be limited to defective resistors, defective switches, defective wiring, and excessive leakage will usually be corrected by cleaning. If repeated cleaning fails to correct the condition, the instrument should be returned to the factory for repair.

4-31. Not only may resistor defects be isolated to a particular step of a decade by the linearity test, but also the nature of the defect may be determined. A resistor may be shorted, open, over value, or under value. Because the switch contacts span two steps of resistance in all decades except the seventh ("G"), the

effect caused directly by a defective resistor will be seen at two adjacent switch positions. In the "D" through "G" decades the linearity test will isolate the defect to a particular resistor. In the "A", "B", and "C", decades each step is made up of several resistors and each resistor in the step will have to be measured to find the defect. In these decades, the variable trimmer resistor in the defective step should be checked by monitoring it and sweeping it from stop to stop several times. If the variation is not smooth, it should be replaced. If one of the resistors in the oil tank or one of the factory selected fixed resistors is found to be defective, the instrument should be returned to the factory for repair.

4-32. A shorted resistor will decrease the overall resistance of the decade thereby increasing the proportional value of all steps except the one containing the shorted resistor. The proportional value of this step will be very low.

4-33. An open resistor in any decade will prevent any output until the switch is advanced so the contacts span the open resistor. At this point the ratio will be high. As the switch is advanced so the contacts no longer span the open resistor, the measured output will be the source voltage. If a decade shunt is open all steps of the decade will be equal but resistance of the decade will be high. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be high; above the midpoint, the output will be low.

4-34. An over value resistor in any decade will reduce the proportion of all other steps and increase the proportion of the step containing the over value resistor. In all decades except the seventh, this increase will be seen at two adjacent switch positions because the switch contacts span two resistance steps. In the seventh decade, there will be only one over value step. If a decade shunt is over value, all steps of the decade will be equal but the resistance of the decade will be high. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be high; above the midpoint, the output will be low.

4-35. An under value resistor in any decade will increase the proportion of all other steps and decrease the proportion of the step containing the under value resistor. In all decades except the seventh, this decrease will be seen at two adjacent switch positions. In the seventh decade there will be only one under value step. If a decade shunt is under value, all steps of the decade will be equal but the resistance of the decade will be low. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be low; above the midpoint, the output will be high.

4-36. A defective switch usually will cause erratic or irregular operation of the decade. A broken contact may cause one step to be missing although all others are of the correct value or it may completely open the divider circuit. When a switch defect is suspected, the switch should be checked for continuity at each position.

4-37. Defective wiring usually will cause one step of a decade to be missing or will completely open the divider circuit. Wiring continuity should be checked to isolate the fault.

4-38. REPAIR

4-39. Any parts of the Model 720A except factory selected resistors and resistors housed in the oil tank may be replaced without difficulty by an experienced electronic maintenance technician. When a switch is replaced all leads should be tagged as they are disconnected to assure that they are correctly connected to the new switch. Care should be exercised in any soldering operation to assure that good electrical contact is made. All parts except precision wirewound resistors may be ordered from the factory by giving only the information specified in paragraph 5-4.

4-40. The precision wirewound resistors used in the Model 720A are selected and matched during manufacture to form a completely matched set. Sufficient information is marked on each of these resistors to permit replacement with a resistor which will match the others in the set. The following information should be given when one of these resistors is ordered from the factory:

a. Serial number of the instrument.

b. Reference designation of the resistor.

c. All markings on the resistor.

If all markings on the defective resistor can not be read, give the following information:

a. Serial number of the instrument.

b. Reference designation of the defective resistor.

c. Reference designation and all part markings of the adjacent resistor on one side.

d. Reference designation and all part markings of the adjacent resistor on the other side.

4-41. SERVICE INFORMATION

4-42. The John Fluke Manufacturing Co., Inc. warrants each instrument manufactured by them for the period of one year upon making delivery of the instrument to you, the original purchaser. Complete warranty page located at the rear of this manual.

4-43. If you should encounter any problem in the operation of your instrument, please feel free to contact your nearest John Fluke Sales Representative or write directly to the John Fluke Manufacturing Co., Inc. with a statement of your problem.

Section 5
List of Replaceable Parts

5-1. INTRODUCTION

5-2. This section contains complete descriptions of those parts one might normally expect to replace during the life of the instrument. The first listing is a breakdown of all of the major assemblies in the instrument. Subsequent listings itemize the components in each assembly. Every listing is accompanied by an illustration identifying each component in the listing. Assemblies and subassemblies are identified by name in the parts list and by a ten digit stock number in the illustrations. Components are identified by the schematic diagram reference designation (e.g. R1, C107 DS1). Parts not appearing on the schematic diagram are numbered consecutively throughout the parts list with a whole number. Flagnotes are used throughout the parts list and refer to ordering explanations. The flagnote explanations appear at the end of the parts list in which they are listed.

5-3. COLUMNAR INFORMATION

a. The REF DESIG column indexes the item description to the associated illustration. In general the reference designations are listed under each assembly in alpha-numeric order. Subassemblies of minor proportions are sometimes listed with the assembly of which they are a part. In this case, the reference designations for the components of the subassembly may appear out of order.

b. The DESCRIPTION column describes the salient characteristics of the component. Indention of the description indicates the relationship to other assemblies, components, etc. In many cases it is necessary to abbreviate in this column. For abbreviations and symbols used, see the following page.

c. The ten-digit part number by which the item is identified at the John Fluke Mfg. Co. is listed in the STOCK NO. column. Use this number when ordering parts from the factory or authorized representatives.

d. The Federal Supply Code for the item manufacturer is listed in the MFR column. An abbreviated list of Federal Supply Codes is included in the Appendix.

e. The part number which uniquely identifies the item to the original manufacturer is listed in the MFR PART NO column. If a component must be ordered by description, the type number is listed.

f. The TOT QTY column lists the total quantity of the item used in the instrument. Second and subsequent listing of the same item are referenced to the first listing with the abbreviation REF. In the case of optional subassemblies, plug ins, etc. that are not always part of the instrument, the TOT QTY column lists the total quantity of the item in that particular assembly.

g. Entries in the REC QTY column indicate the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of every part in the instrument be stocked.

h. The USE CODE column identifies certain parts which have been added, deleted or modified during the production of the instrument. Each part for which a Use Code has been assigned may be identified with a particular instrument serial number by consulting the Serial Number Effectivity List. As Use Codes are added to the list, the TOT QTY column listings are changed to reflect the most current information. Sometimes when a part is changed, the new part can and should be used as a replacement for the original part. In this event a parenthetical note is added in the DESCRIPTION column.

5-4. HOW TO OBTAIN PARTS

5-5. Standard components have been used wherever possible. Standard components may be ordered directly from the manufacturer by using the manufacturer's part number, or parts may be ordered from the John Fluke Mfg. Co. factory or authorized representative by using the Fluke part number. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

5-6. You can insure prompt and efficient handling of your order to the John Fluke Mfg. Co. if you include the following information:

a. Quantity.

b. FLUKE Stock Number.

c. Description.

d. Reference Designation.

e. Instrument model and serial number.

Example; 2 each, 4805-177105, Transistors, 2N3565, Q107-108 for 845AR, s/n 168.

If you must order structural parts not listed in the parts list, describe the part as completely as possible. A sketch of the part showing its location to other parts of the instrument is usually most helpful.

5-8. SERIAL NUMBER EFFECTIVITY

5-9. A Use Code column is provided to identify certain parts that have been added, deleted, or modified during production of the Model 720A. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity List below. All parts with no code are used on all instruments with serial numbers above 123. New codes will be added as required by instrument changes.

USE CODE	EFFECTIVITY
No Code	Model 720A, serial number 123 and on.
A	Model 720A, serial number 536 and on.

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	KELVIN-VARLEY VOLTAGE DIVIDER **Figure 5-1**	720A					
	Front Panel Assembly (See Figure 5-2)						
	Trimmer P/C Assembly (See Figure 5-3)	1702-210716 (720A-4001)	89536	1702-210716	1		
	Bridge P/C Assembly (See Figure 5-4)	1702-200295 (720A-4002)	89536	1702-200295	1		
	Resistor Can Assembly If a resistor in this assembly requires replacement, the entire instrument must be returned to the factory for repair and recalibration.	3158-217612 (720A-4018)	89536	3158-217612	1		
S1	Switch, "A" DECADE, rotary, 3p, 12 pos, 3 sect	5105-220012	89536	5105-220012	1		
	"B" Decade Switch Assembly (See Figure 5-5)	5110-217307 (720A-4004)	89536	5110-217307	1		
	"C" Decade Switch Assembly (See Figure 5-6)	5110-217315 (720A-4005)	89536	5110-217315	1		
	"D", "E", "F" and "G" Decades Switch Assy. (See Figure 5-7)	5110-217323 (720A-4006)	89536	5110-217323	1		
S8	Switch, FUNCTION, 5p, 11 pos, 5 sect	5105-220020	89536	5105-220020	1		
S9	Switch, INTERNAL FUNCTION, 4p, 3 pos, 2 sect	5107-218560	89536	5107-218560	1		
1	Bushing, dial	2502-130435	89536	2502-130435	7		
1	Bushing, dial	3153-130252	89536	3153-130252	7		A
2	Coupler, switch (not illustrated)	2402-200592	89536	2402-200592	7		
3	Cover, bottom (not illustrated)	3156-217117	89536	3156-217117	1		
4	Cover, internal function switch	3156-217521	89536	3156-217521	1		
5	Cover, top (not illustrated)	3156-217125	89536	3156-217125	1		
6	Detent, switch	5108-218578	89536	5108-218578	6		
7	Detent, internal function switch (not illustrated)	5108-218552	89536	5108-218552	1		
8	Dial, 0.0 - 1.0 Cal	2403-208611	89536	2403-208611	1		
9	Dial, 0 - Cal	2403-208595	89536	2403-208595	2		
10	Dial, 0 - X	2403-208603	89536	2403-208603	1		
11	Dial, 0 - 9	2403-208587	89536	2403-208587	3		
12	Foot, rubber (not illustrated)	2819-103309	77969	9102-W	4		
13	Heat sink, resistor	3156-217463	89536	3156-217463	1		
14	Knob, INTERNAL FUNCTION	2405-170050	89536	2405-170050	1		
15	Panel, rear	3156-217075	89536	3156-217075	1		

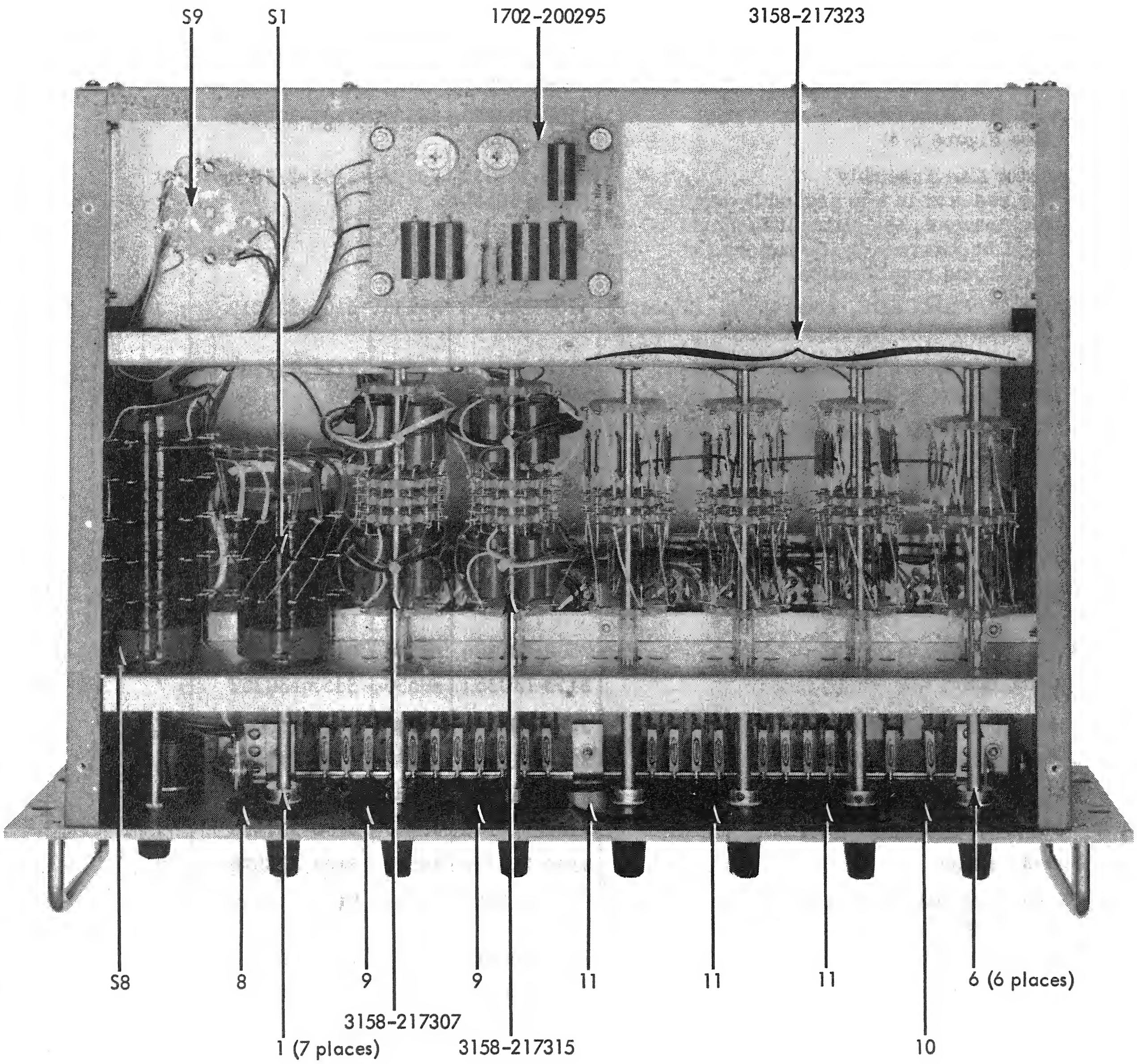


Figure 5-1. 720A KELVIN-VARLEY VOLTAGE DIVIDER (Sheet 1 of 2)

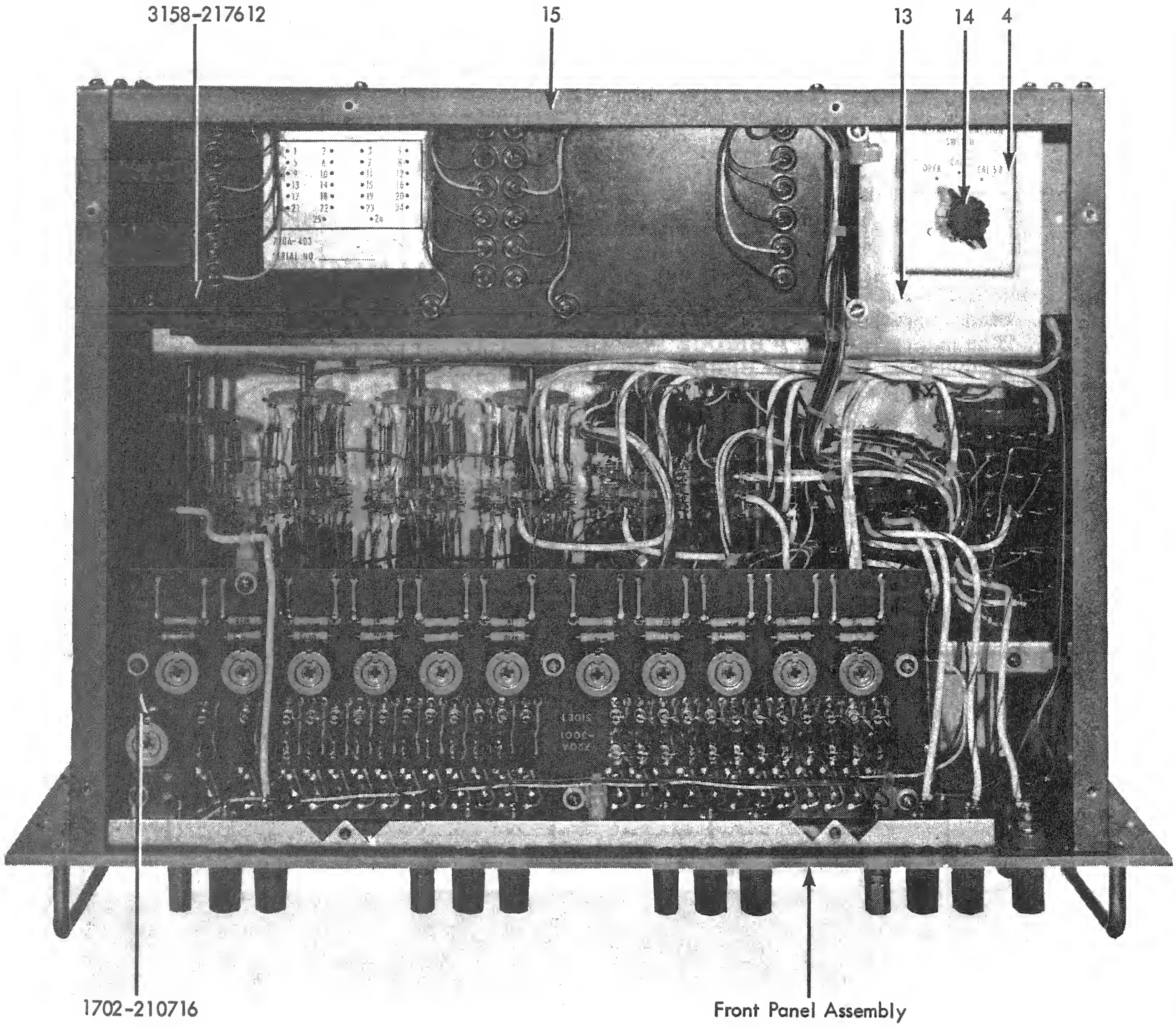


Figure 5-1. 720A KELVIN-VARLEY VOLTAGE DIVIDER (Sheet 2 of 2)

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	FRONT PANEL ASSEMBLY - Figure 5-2						
J1	Binding post, red, 1.1 INPUT	2811-149856	58474	BHB-10208-G22	5		
J2	Binding post, red, 1.0 INPUT	2811-149856	58474	BHB-10208-G22	REF		
J3	Binding post, black, LOW INPUT	2811-149864	58474	BHB-10208-G21	4		
J4	Binding post, GROUND INPUT	2811-155911	58474	GP30NC	4		
J5	Binding post, red, HIGH OUTPUT	2811-149856	58474	BHB-10208-G22	REF		
J6	Binding post, black, LOW OUTPUT	2811-149864	58474	BHB-10208-G21	REF		
J7	Binding post, GROUND OUTPUT	2811-155911	58474	GP30NC	REF		
J8	Binding post, black, - BRIDGE DETECTOR	2811-149864	58474	BHB-10208-G21	REF		
J9	Binding post, red, + BRIDGE DETECTOR	2811-149856	58474	BHB-10208-G22	REF		
J10	Binding post, GROUND BRIDGE DETECTOR	2811-155911	58474	GP30NC	REF		
J11	Binding post, red, + BRIDGE POWER	2811-149856	58474	BHB-10208-G22	REF		
J12	Binding post, black, - BRIDGE POWER	2811-149864	58474	BHB-10208-G21	REF		
J13	Binding post, GROUND BRIDGE POWER	2811-155911	58474	GP30NC	REF		
R1	Res, var, ww, 5k ±3%, 3w, BRIDGE BALANCE (not illustrated)	4702-215319	89536	4702-215319	1		
16	Cover, calibration access	3156-217083	89536	3156-217083	1		
17	Handle, chrome-plated brass	2404-101683	15849	1010-13	2		
18	Knob, A through G	2405-158949	89536	2405-158949	7		
19	Knob, BRIDGE BALANCE	2405-158956	89536	2405-158956	1		
20	Knob, FUNCTION	2405-190249	89536	2405-190249	1		
21	Panel, front	1406-217042	89536	1406-217042	1		

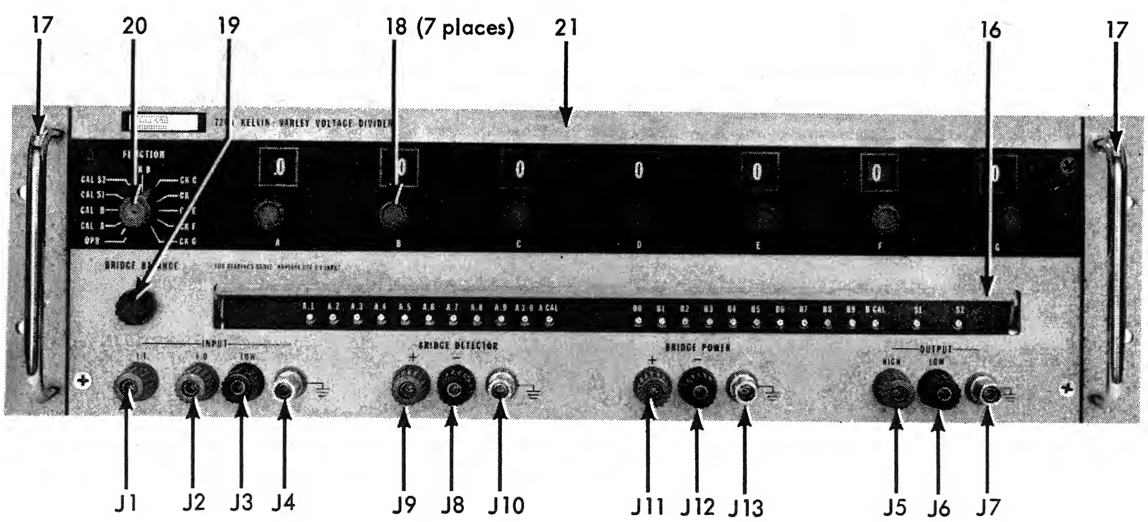


Figure 5-2. FRONT PANEL ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	TRIMMER P/C ASSEMBLY - Figure 5-3	1702-210716 (720A-4001)	89536	1702-210716	REF		
R1001	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	24		
R1002	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	12		
R1003	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	23	1	
R1004	Res, ww, factory selected	1					
R1005	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1006	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1007	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1008	Res, ww, factory selected	1					
R1009	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1010	Res, met flm, 8.45k ±1%, 1/2w	4702-159475	12400	Type CEC-TO	REF		
R1011	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1012	Res, ww, factory selected	1					
R1013	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1014	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1015	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1016	Res, ww, factory selected	1					
R1017	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1018	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1019	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1020	Res, ww, factory selected	1					
R1021	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1022	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1023	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1024	Res, ww, factory selected	1					
R1025	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1026	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1027	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1028	Res, ww, factory selected	1					
R1029	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1030	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1031	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1032	Res, ww, factory selected	1					
R1033	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1034	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1035	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1036	Res, ww, factory selected	1					
R1037	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1038	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1039	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1040	Res, ww, factory selected	1					
R1041	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1042	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1043	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1044	Res, ww, factory selected	1					
R1045	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1046	Res, ww, factory selected	1					
R1047	Res, ww, factory selected	1					
R1048	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		

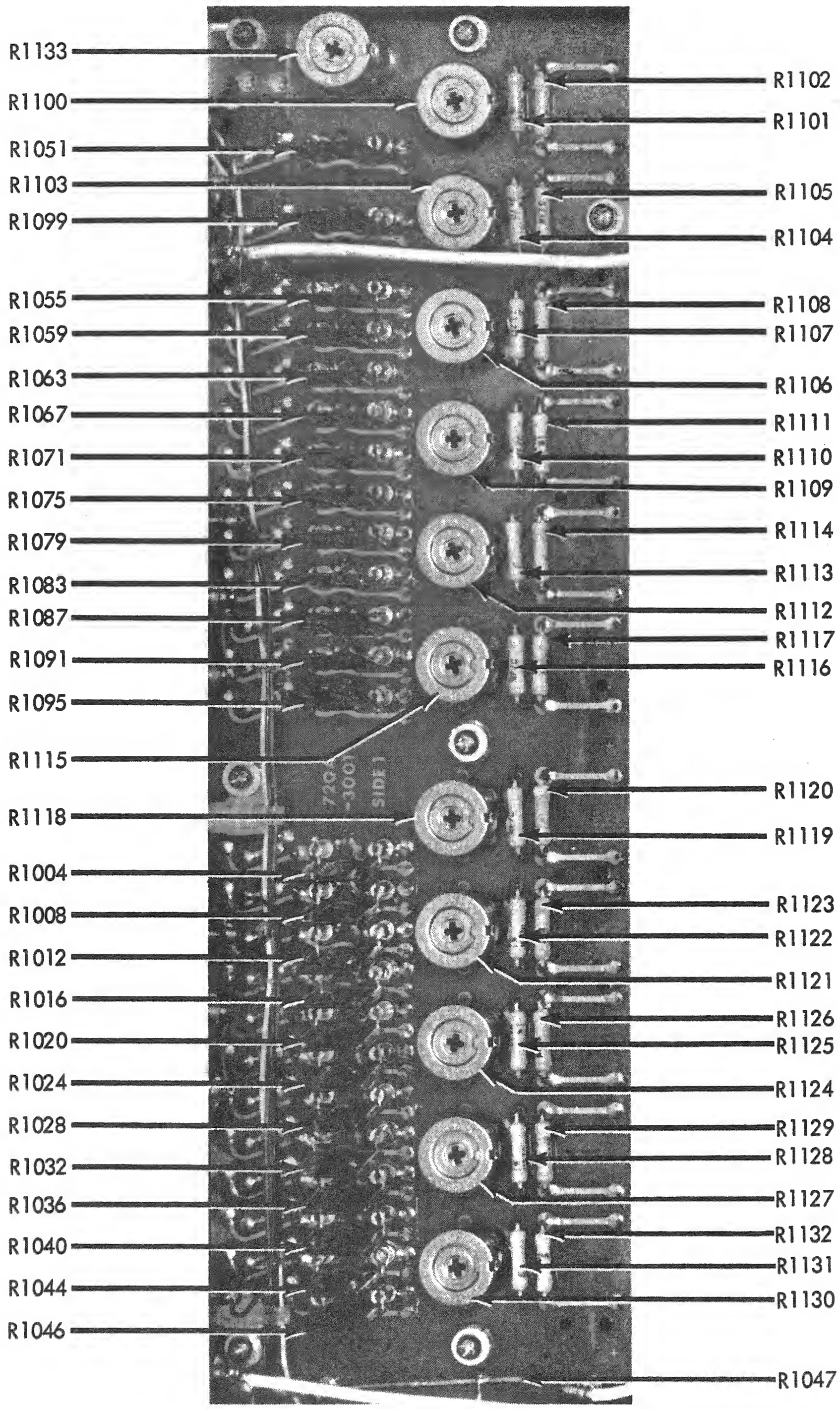


Figure 5-3. TRIMMER P/C ASSEMBLY (Sheet 1 of 2)

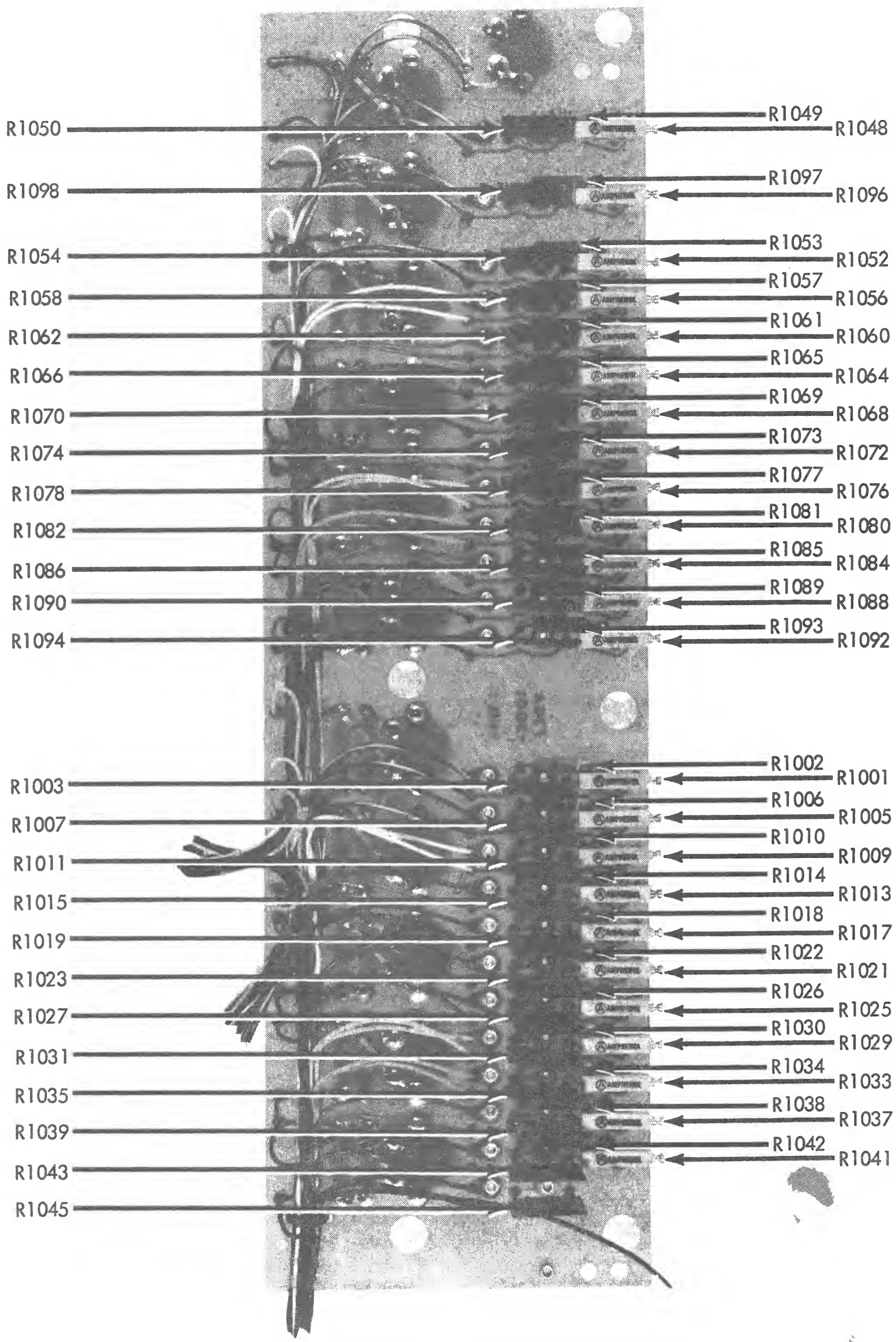


Figure 5-3. TRIMMER P/C ASSEMBLY (Sheet 2 of 2)

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R1049	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1050	Res, ww, 250Ω ±0.5%, 1/2w	4707-199893	89536	4707-199893	1	1	
R1051	Res, ww, factory selected	1					
R1052	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1053	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	12		
R1054	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1055	Res, ww, factory selected	1					
R1056	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1057	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1058	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1059	Res, ww, factory selected	1					
R1060	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1061	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1062	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1063	Res, ww, factory selected	1					
R1064	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1065	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1066	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1067	Res, ww, factory selected	1					
R1068	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1069	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1070	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1071	Res, ww, factory selected	1					
R1072	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1073	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1074	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1075	Res, ww, factory selected	1					
R1076	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1077	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1078	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1079	Res, ww, factory selected	1					
R1080	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1081	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1082	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1083	Res, ww, factory selected	1					
R1084	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1085	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1086	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1087	Res, ww, factory selected	1					
R1088	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1089	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1090	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1091	Res, ww, factory selected	1					
R1092	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1093	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1094	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1095	Res, ww, factory selected	1					
R1096	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1097	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1098	Res, ww, 400Ω ±0.25%, 1/2w	4707-131698	89536	4707-131698	1		

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R1099	Res, ww, factory selected	1					
R1100	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	11		
R1101	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	11		
R1102	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	11		
R1103	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1104	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1105	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1106	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1107	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1108	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1109	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1110	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1111	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1112	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1113	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1114	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1115	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1116	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1117	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1118	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1119	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1120	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1121	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1122	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1123	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1124	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1125	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1126	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1127	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1128	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1129	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1130	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1131	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1132	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1133	Res, var, ww, 150Ω ±20%, 1 1/4w	4702-163642	71450	Type 110	1		

1 These resistors are factory selected. Replace with exact value. When ordering, include model, serial number, reference designation and all information stamped on the resistor.

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	BRIDGE P/C ASSEMBLY - Figure 5-4	1702-200295 (720A-4002)	89536	1702-200295	REF		
R201	Res, ww, 39.536k, matched set	2					
R202	Res, ww, 39.536k, matched set	2					
R203	Res, var, ww, 100Ω ±20%, 1 1/4w	4702-112797	71450	Type 110	2		
R204	Res, ww, 15.814k ±0.02%, 1w	4707-200550	89536	4707-200550	1	1	
R205	Res, var, ww, 100Ω ±20%, 1 1/4w	4702-112797	71450	Type 110	REF		
R206	Res, ww, 4.873k, matched set	3					
R207	Res, ww, 4.873k, matched set	3					
R208	Res, met flm, 15k ±1%, 1/2w	4705-151498	12400	Type CEC-TO	1		
R209	Res, ww, 250Ω ±0.5%, 1/2w	4707-199893	89536	4707-199893	1	1	

2 These resistors are factory matched. If replacement is required, an entire set, part number 4710-217679, must be ordered.

3 These resistors are factory matched. If replacement is required, an entire set, part number 4710-217687, must be ordered.

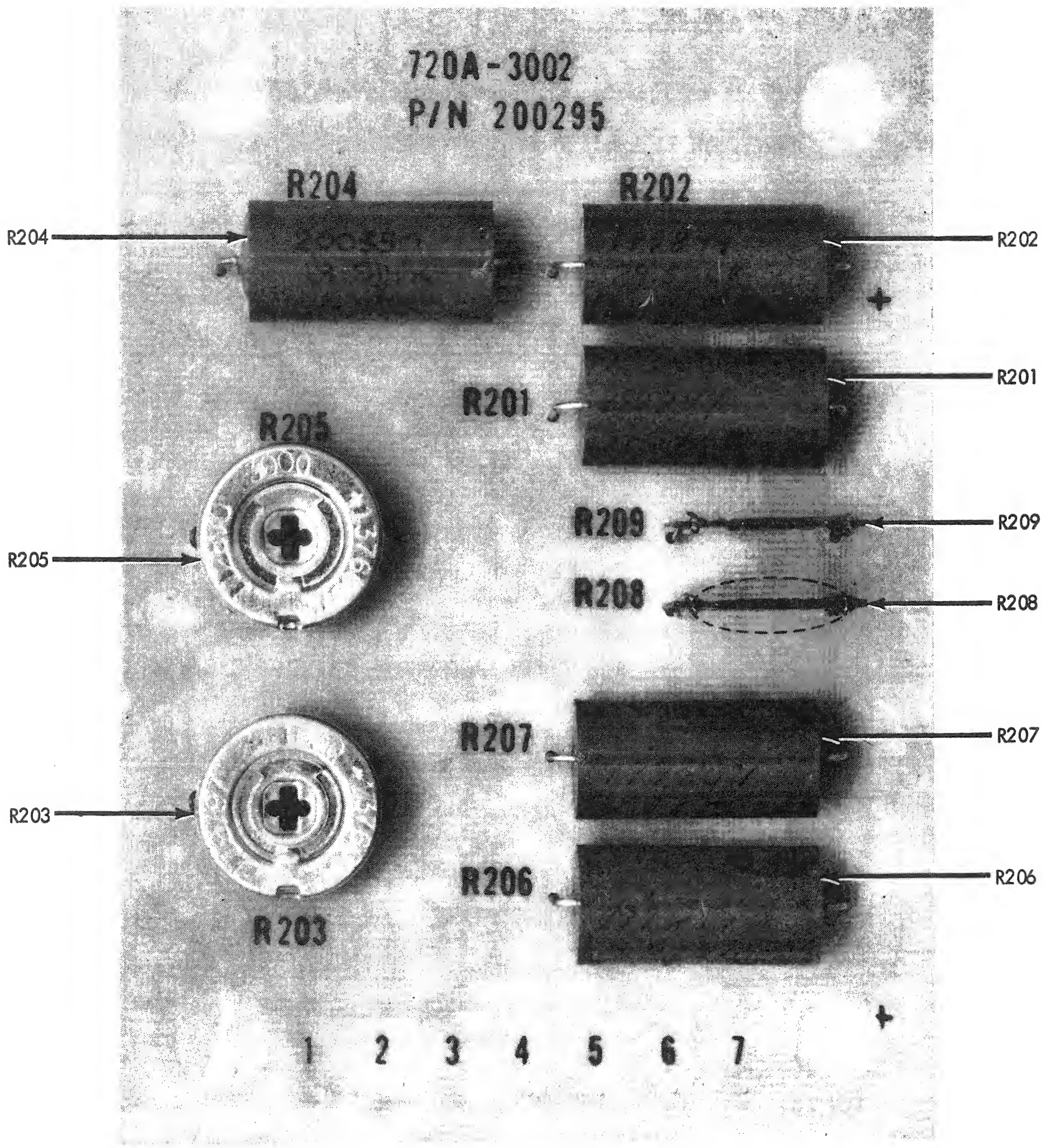
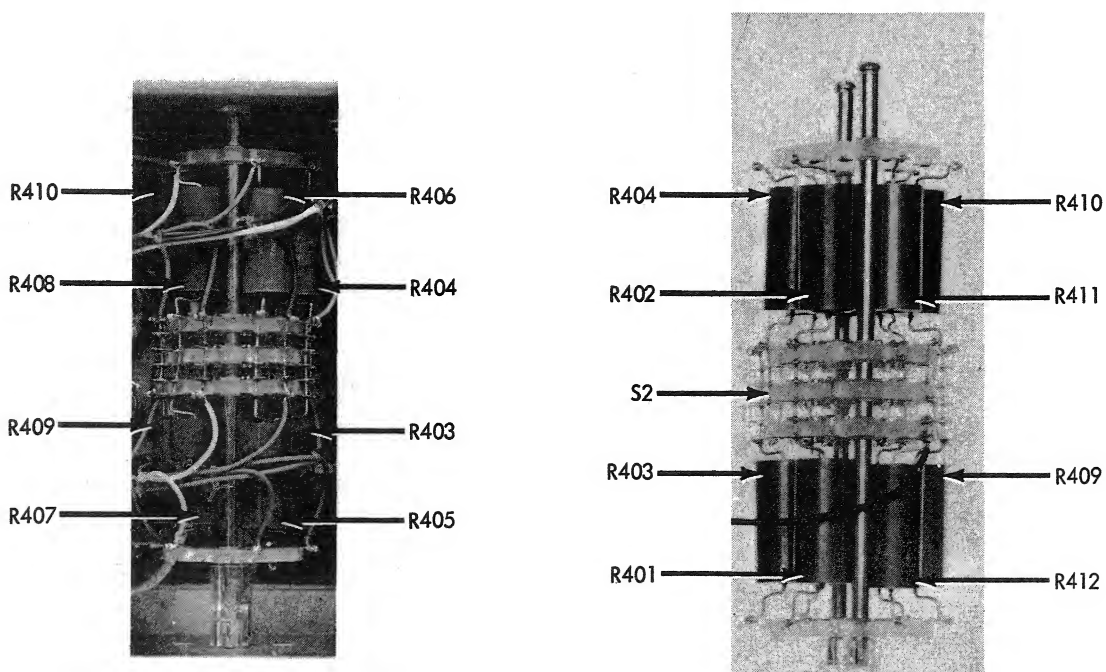


Figure 5-4. BRIDGE P/C ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"B" DECADE SWITCH ASSEMBLY **Figure 5-5**	5110-217307 (720A-4004)	89536	5110-217307	REF		
R401 thru R411	Res, ww, 9.898k, matched set	4					
R412	Res, ww, 39.536k ±0.01%, 1w	4707-199810	89536	4707-199810	1	1	
S2	Switch, "B", rotary, 3p, 11 pos, 5 sect	5107-218602	89536	5107-218602	2		

4 These resistors are a factory matched set, part number 4710-217646. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.



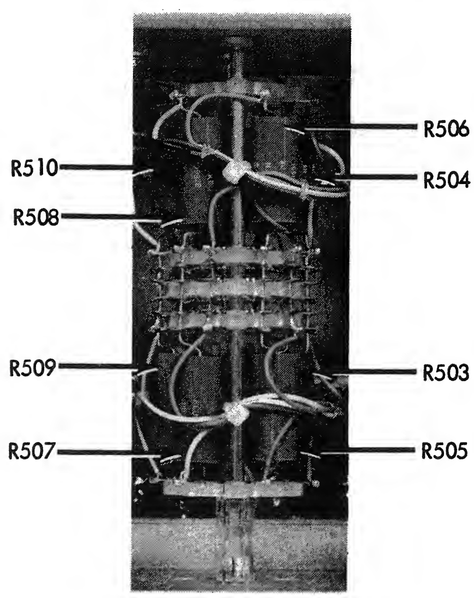
TOP VIEW

BOTTOM VIEW

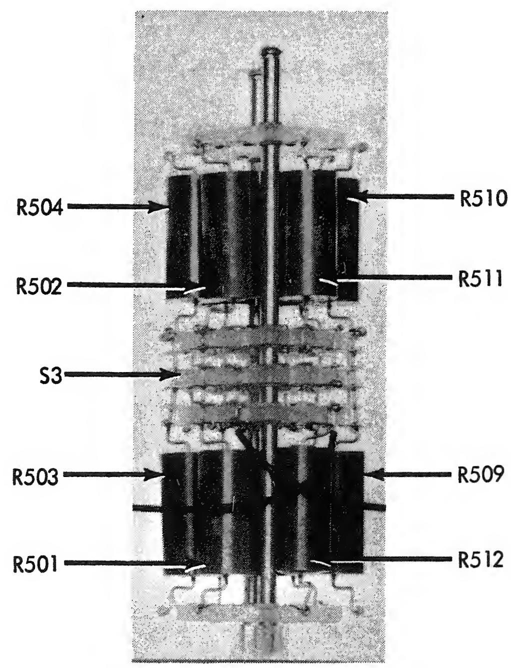
Figure 5-5. "B" DECADE SWITCH ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"C" DECADE SWITCH ASSEMBLY Figure 5-6	5110-217315 (720A-4005)	89536	5110-217315	REF		
R501 thru R511	Res, ww, 4k, matched set	5					
R512	Res, ww, 40.31k ±0.02%, 1w	4707-199836	89536	4707-199836	1	1	
S3	Switch, "C", rotary, 3p, 11 pos, 5 sect	5107-218602	89536	5107-218602	REF		

5 These resistors are a factory matched set, part number 4710-217653. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.



TOP VIEW



BOTTOM VIEW

Figure 5-6. "C" DECADE SWITCH ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"D","E","F", AND "G" DECADES SWITCH ASSEMBLY - Figure 5-7	5110-217323 (720A-4006)	89536	5110-217323	REF		
R601 thru R611	Res, ww, 1k, matched set	6					
R612	Res, ww, 2.5k, matched set	6					
R701 thru R711	Res, ww, 1k, matched set	6					
R712	Res, ww, 2.5k, matched set	6					
R801 thru R811	Res, ww, 1k, matched set	6					
R812	Res, ww, 2.5k, matched set	6					
R901 thru R910	Res, ww, 1k, matched set	6					
S4	Switch, "D", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	3		
S5	Switch, "E", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	REF		
S6	Switch, "F", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	REF		
S7	Switch, "G", rotary, 1p, 11 pos, 3 sect	5107-218586	89536	5107-218586	1		

6 These resistors are a factory matched set, part number 4710-217661. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.

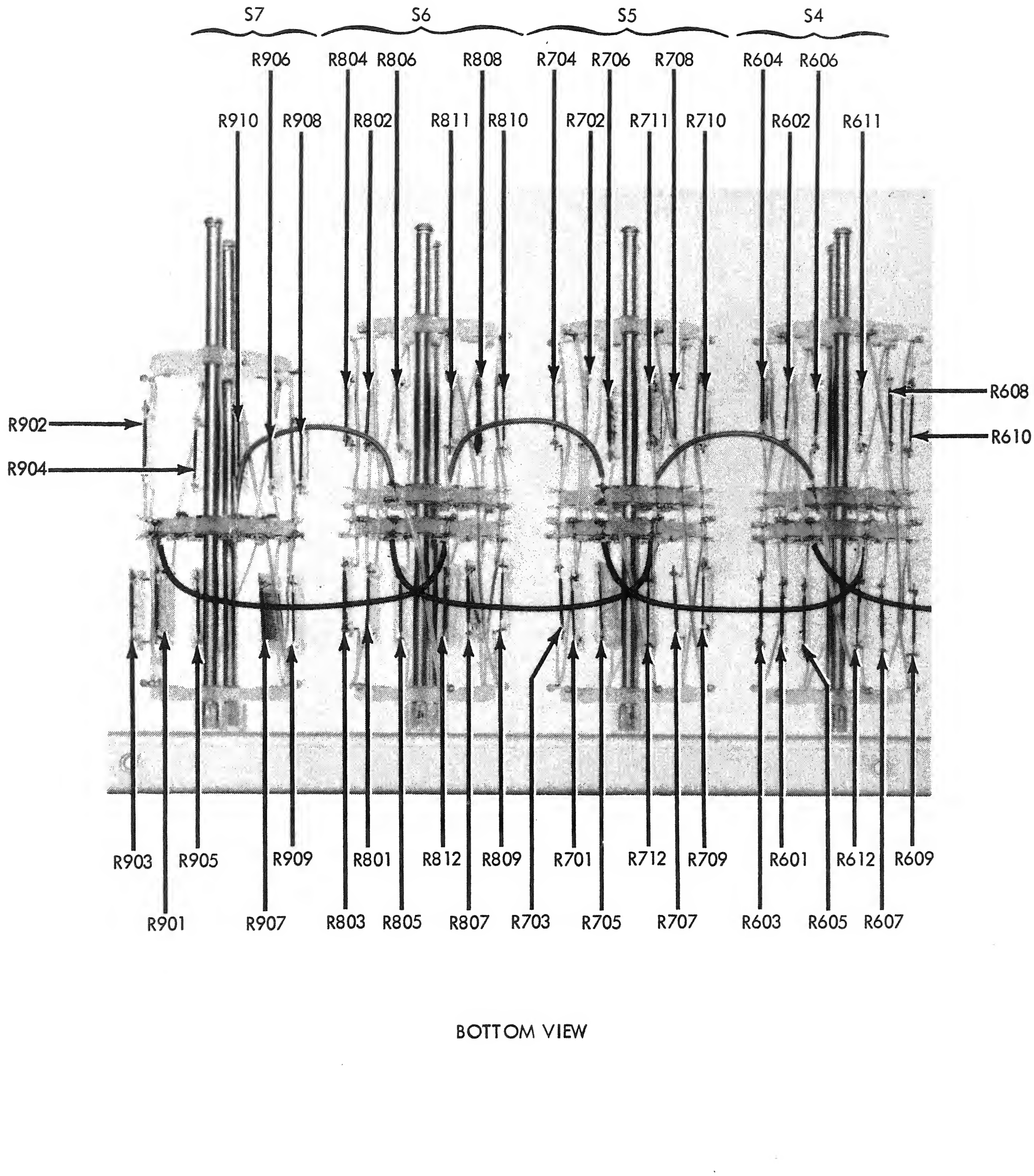


Figure 5-7. "D","E","F" AND "G" DECADES SWITCH ASSEMBLY

Section 7

General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5.

Federal Supply Codes for Manufacturers

D9816
Westermann Wilhelm Augusta-Anlage
Mannheim-Nackarau Germany

S0482
Sony Corp.
Tokyo, Japan

S3774
Oshino Electric Lamp Works
Tokoyo, Japan

0AD86
IN General
El Paso, TX

0AE89
Autosplice Inc.
Woodside, NY

0BW21
Noritake Co. Inc.
Burlington, MA

0ANF0
Topaz Semiconductor Inc
San Jose, CA

0DSM7
Conductive (Pkg) Containers Inc.
Brookfield, WI

0CLN7
Emhart Fastening Group
Shelton, CT

0FB81
S-Mos Systems Inc.
San Jose, CA

0FFP1
Eveready LTD
Ever Ready Special Battery Div.
Dawley Telford Salop UK

00199
Marcon Electronics Corp
Keamy, NJ

00213
Nytronics Comp. Group Inc.
Darrlingon, NC

00327
Welwyn International Inc.
Westlake, OH

00656
Aerovox Corp.
New Bedford, MA

00686
Film Capacitors Inc.
Passaic, NJ

00779
AMP, Inc.
Harrisburg, Pennsylvania

00853
Sangamo Weston Inc
Components Div
Pickens, NC

01091
Allied Plastics Co.
Los Angeles, CA

01101
Wabash Inc
(Formerly Wabash Magnetics)
Wabash, IN

01121
Allen Bradley Co.
Milwaukee, WI

01281
TRW Electronics & Defense Sector
R F Devices
Lawndale, CA

01295
TX Instruments Inc.
Semiconductor Group
Dallas, TX

01526
Genicom
Waynesboro, VA

01537
Motorola Communications &
Electronics Inc.
Franklin Park, IL

01686
RCL Electronics/Shallcross Inc.
Electro Components Div.
Manchester, NH

01884
Sprague Electric Co.
(Now 56289)

01961
Varian Associates Inc.
Pulse Engineering Div.
Convoy, CT

01963
Cherry Electrical Products Corp
Waukegan, IL

02111
Spectrol Electronics Corp.
City of Industry, CA

02114
Amperex Electronic Corp.
Ferrox Cube Div.
Saugerties, NY

02131
General Instrument Corp.
Government Systems Div.
Westwood, MA

02395
Sonar Radio Corp.
Hollywood, FL

02533
Leigh Instruments Ltd.
Frequency Control Div.
Don Mills, Ontario, Canada

02606
Fenwal Labs
Division of Travenal Labs
Morton Grove, IL

02660
Bunker Ramo-Eltra Corp.
Amphenol NA Div.
Broadview, IL

02697
Parker-Hannifin Corp.
O-Ring Div
Lexington, KY

02735
RCA-Solid State Div.
Somerville, NJ

02768
ITW (IL Tool Works)
Fastex Division
Des Plaines, IL

02799
Arco Electronics Inc.
Chatsworth, CA

03296
Nylon Molding Corp.
Monrovia, CA

03445
Lercon Electronics Inc
Burbank, CA

03508
General Electric Co.
Semiconductor Products
& Batteries
Auburn, NY

03797
Genisco Technology Corp.
Eltronics Div.
Rancho Dominquez, CA

03877
Gilbert Engineering Co.Inc
Incon Sub of Transitron
Electronic Corp.
Glendale, AZ

03888
KDI Electronics Inc.
Pyrofilm Div.
Whippany, NJ

03911
Clairex Corp.
Clairex Electronics Div.
Mount Vernon, NY

03980
Muirhead Inc.
Mountainside, NJ

04009
Cooper Industries, Inc.
Arrow Hart Div.
Hartford, CT

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, CA

04221
Midland-Ross Corp.
Midtex Div.
N. Mankato, MN

04222
AVX Corp.
AVX Ceramics Div.
Myrtle Beach, SC

04423
Telonic Berkley Inc.
Laguna Beach, CA

04713
Motorola Inc.
Semiconductor Group
Phoenix, AZ

04946
Standard Wire and Cable
Rancho Dominquez, CA

05173
General Radio
NY,NY.
Replaced by:

24655
Genrad,INC.
Concord, MA

05236
Jonathan Mfg. Co.
Fullerton, CA

05245
Corcom Inc.
Libertyville, IL

05276
ITT Pomona
Electronics Div.
Pomona, CA

05277
Westinghouse Elec. Corp.
Semiconductor Div.
Youngwood, PA

05347
Ultronix Inc
Grand Junction, CO

05397
Union Carbide Corp.
Materials Systems Div.
Cleveland. OH

05571
Sprague Electric Co.
(Now 56289)

05574
Viking Connectors Inc
Sub of Criton Corp.
Chatsworth, CA

05791
LYN-TRON
Burbank, CA

05820
EG & G Wakefield Engineering
Wakefield, MA

05839
Advance Electrical
Chicago, IL

05972
Loctite Corp.
Newington, CT

06001
General Electric Co.
Electric Capacitor Product
Section
Columbia, SC

06141
Fairchild Weston Systems Inc.
Data Systems Div.
Sarasota, FL

06192
La Deau Mfg. Co.
Glendale, CA

06229
Electrovert Inc.
Elmsford, NY

06383
Panduit Corp.
Tinley Park, IL

06473
Bunker Ramo Corp.
Amphenol NA Div.
SAMS Operation
Chatsworth, CA

06540
Mite Corp
Amatom-Electrical Div

06555
Beede Electrical Instrument
Penacook, NH

06665
Precision Monolithics
Sub of Bourns Inc.
Santa Clara, CA

06666
General Devices Co. Inc.
INpolis, IN

06739
Electron Corp.
Littleton, CO

06743
Gould Inc.
Foil Div.
Eastlake, OH

06751
Components Inc.
Semcor Div.
Phoenix, AZ

06776
Robinson Nugent Inc.
New Albany, IN

06915
Richco Plastic Co.
Chicago, IL

06961
Vernitron Corp.
Piezo Electric Div.
Bedford, OH

06980
EIMAC
(See Varian)
San Carlos, CA

07047
Ross Milton Co., The
Southampton, PA

07138
Westinghouse Electric Corp.
Industrial & Government
Tube Div.
Horseheads, NY

07233
Benchmark Technology Inc.
City of Industry, CA

07239
Biddle Instruments
Blue Bell, PA

07256
Silicon Transistor Corp.
Sub of BBF Inc.
Chelmsford, MA

07261
Avnet Corp.
Culver City, CA

07263
Fairchild Semiconductor
North American Sales
Ridgeview, CT

07344
Bircher Co. Inc., The
Rochester, NY

07374
Optron Corp
Woodbridge, CT

07557
Campion Co. Inc.
Philadelphia, PA

07597
Burndy Corp.
Tape/Cable Div.
Rochester, NY

07716
TRW Inc. (Can use 11502)
IRC Fixed Resistors/
Burlington
Burlington, VT

07792
Lerma Engineering Corp.
Northampton, MA

07810
Bock Corp.
Madison, WI

07910
Teledyne Semiconductor
Mtn. View, CA

07933
Raytheon Co.
Semiconductor Div.
Mountain View, CA

08FG6
Calmos Systems Inc.
Kanata, Ont. Canada

080A9
Dallas Semiconductor
Dallas, TX

08111
MF Electronics
New Rochelle, NY

08235
Industro Transistor Corp.
Long Island City, NY

08261
Spectra-Strip
An Eltra Co.
Garden Grove, CA

08445
Electri-Cord Mfg., Inc
Westfield, PA

08530
Reliance Mica Corp.
Brooklyn, NY

08718
ITT Cannon Electric
Phoenix Div.
Phoenix, AZ

08806
General Electric Co.
Minature Lamp Products
Cleveland, OH

08863
Nylomatic
Fallsington, PA

08988
Skottie Electronics Inc.
Archbald, PA

09021
Airco Inc.
Airco Electronics
Bradford, PA

09023
Cornell-Dublier Electronics
Fuquay-Varina, NC

09214
General Electric Co.
Semiconductor Products Dept.
Auburn, NY

09353
C and K Components Inc.
Newton, MA

09423
Scientific Components Inc.
Santa Barbara, CA

09922
Burndy Corp.
Norwalk, CT

09969
Dale Electronics Inc.
Yankton, SD

09975
Burroughs Corp.
Electronics Components
Detroit, MI

1A791
LFE Electronics
Danvers, MA

1B715
(United Shoe & Nylock Corp)
-Nylock Fastener Corp.-
Paramus, NJ

10059
Barker Engineering Corp.
Kenilworth, NJ

10389
IL Tool Works Inc.
Licon Div.
Chicago, IL

11236
CTS Corp.
Resistor Products Div.
Berne, IN

11237
CTS Corp of CA
Electro Mechanical Div.
Paso Robles, CA

11295
ECM Motor Co.
Schaumburg, IL

11358
Columbia Broadcasting System
CBS Electronic Div.
Newburyport, MA

11403
Vacuum Can Co.
Best Coffee Maker Div.
Chicago, IL

11502 (can also use 35009)
TRW Inc.
TRW Resistive Products Div.
Boone, NC

11503
Keystone Columbia Inc.
Freemont, IN

11532
Teledyne Relays Teledyne
Industries Inc.
Hawthorne, CA

11711
General Instrument Corp.
Rectifier Div.
Hicksville, NY

11726
Qualidyne Corp.
Santa Clara, CA

12014
Chicago Rivet & Machine Co.
Naperville, IL

12020
Ovenaire
Div. of Electronic Technologies
Charlottesville, VA

12038
Simco
(Div of Ransburg Corp)
Hatfield, PA

12040
National Semiconductor Corp.
Danbury, CT

12060
Diodes Inc.
Northridge, CA

12136
PHC Industries Inc.
Formerly Philadelphia Handle Co.
Camden, NJ

12300
AMF Canada Ltd.
Potter-Brumfield
Guelph, Ontario, Canada

12323
Practical Automation Inc.
Shelton, CT

12327
Freeway Corp.
Cleveland, OH

12406
Elpac Electronics Inc.
Santa Ana, CA

12443
Budd Co.,The
Plastics Products Div.
Phoenixville, PA

12581
Hitachi Metals Inernational Ltd.
Hitachi Magna-Lock Div.
Big Rapids, MO

12615
US Terminals Inc.
Cincinnati, OH

12617
Hamlin Inc.
LaKe Mills, WI

12673
Wesco Electrical
Greenfield, MA

12697
Clarostat Mfg. Co. Inc.
Dover, NH

12749
James Electronic Inc.
Chicago, IL

12856
MicroMetals Inc.
Anaheim, CA

12881
Metex Corp.
Edison, NJ

12895
Cleveland Electric Motor Co.
Cleveland, OH

12954
Microsemi Corp.
Components Group
Scottsdale, AZ

12969
Unitrode Corp.
Lexington, MA

13050
Potter Co.
Wesson, MS

13103
Thermalloy Co., Inc.
Dallas, TX

13327
Solitron Devices Inc.
Tappan, NY

13511
Bunker-Ramo Corp.
Amphenol Cadre Div.
Los Gatos, CA

13606
Sprague Electric Co.
(Use 56289)

13689
SPS Technologies Inc.
Hatfield, NJ

13764
Micro Plastics
Flippin, AZ

13919
Burr-Brown Research Corp.
Tucson, AZ

14099
Semtech Corp.
Newbury Park, CA

14140
McGray-Edison Co.
Commercial Development Div.
Manchester, NH

14189
Ortronics, Inc.
Orlando, FL

14193
Cal-R-Inc.
Santa Monica, CA

14301
Anderson Electronics
Hollidaysburg, PA

14329
Wells Electronics Inc.
South Bend, IN

14482
Watkins-Johnson Co.
Palo Alto, CA

14552
Microsemi Corp.
(Formerly Micro-Semiconductor)
Santa Ana, CA

14604
Elmwood Sensors, Inc
Pawtucket, RI

14655
Cornell-Dublier Electronics
Div. of Federal Pacific
Electric Co. Govt Cont Dept.
Newark, NJ

14704
Crydom Controls
(Division of Int Rectifier)
El Segundo, CA

14752
Electro Cube Inc.
San Gabriel, CA

14936
General Instrument Corp.
Discrete Semi Conductor Div.
Hicksville, NY

14949
Trompeter Electronics
Chatsworth, CA

15412
Amtron
Midlothian, IL

15542
Scientific Components Corp.
Mini-Circuits Laboratory Div.
Brooklyn, NY

15636
Elec-Trol Inc.
Saugus, CA

15782
Bausch & Lomb Inc.
Graphics & Control Div.
Austin, TX

15801
Fenwal Eletronics Inc.
Div. of Kidde Inc.
Framingham, MA

15818
Teledyne Inc. Co.
Teledyne Semiconductor Div.
Mountain View, CA

15849
Useco Inc.
(Now 88245)

15898
International Business
Machines Corp.
Essex Junction, VT

16068
International Diode Div.
Harrison, NJ

16162
MMI
Southfield, MI

16245
Conap Inc.
Olean, NY

16258
Space-Lok Inc.
Burbank, CA

16352
Codi Corp.
Linden, NJ

16469
MCL Inc.
LaGrange, IL

16473
Cambridge Scientific Industries
Div. of Chemed Corp.
Cambridge, MD

16733
Cablewave Systems Inc.
North Haven, CT

16742
Paramount Plastics
Fabricators Inc.
Downey, CA

16758
General Motors Corp.
Delco Electronics Div.
Kokomo, IN

17069
Circuit Structures Lab
Burbank, CA

17117
Electronic Molding Corp.
Woonsocket, RI

17338
High Pressure Eng. Co. Inc.
OK City, OK

17504
Aluminum Filter Co.
Carpinteria, CA

17545
Atlantic Semiconductors Inc.
Asbury Park, NJ

17745
Angstrohm Precision, Inc.
Hagerstown, MD

17856
Siliconix Inc.
Santa Clara, CA

18178
E G & Gvactee Inc.
St. Louis, MO

18235
KRL/Bantry Components Inc.
Manchester, NH

18310
Concord Electronics
New York, NY

18324
Signetics Corp.
Sacramento, CA

18377
Parlex Corp.
Methuen, MA

18520
Sharp Electronics Corp.
Paramus, NJ

18542
Wabash Inc.
Wabash Relay & Electronics Div.
Wabash, IN

18565
Chomerics Inc.
Woburn, MA

18612
Vishay Intertechnology Inc.
Vishay Resistor Products Group
Malvern, PA

18632
Norton-Chemplast
Santa Monica, CA

18677
Scanbe Mfg. Co.
Div. of Zero Corp.
El Monte, CA

18736
Voltronics Corp.
East Hanover, NJ

18786
Micro-Power
Long Island City, NY

18927
GTE Products Corp.
Precision Material Products
Business Parts Div.
Titusville,PA

19080
Robinson Electronics Inc.
San Luis Obispo, CA

19112
Garry Corp.
Langhorne, PA

19315
Bendix Corp., The
Navigation & Control Group
Terboro, NJ

19451
Perine Machine Tool Corp.
Kent, WA

19482
Delta Electronics
Alexandria, VA

19613
MN Mining & Mfg. Co.
Textool Products Dept.
Electronic Product Div.
Irving, TX

19647
Caddock Electronics Inc.
Riverside, CA

19701
Mepco/Centralab Inc.
A N. American Philips Co.
Mineral Wells, TX

2B178
Wire Products
Cleveland, OH

2K262
Boyd Corporation
Portland, OR

2Y384
North American Philips Lighting Corp.
Van Wert, OH

20584
Enochs Mfg. Inc.
INpolis, IN

20891
Cosar Corp.
Dallas, TX

21317
Electronics Applications Co.
El Monte, CA

21604
Buckeye Stamping Co.
Columbus, OH

21845
Solitron Devices Inc.
Semiconductor Group
Rivera Beach, FL

21847
Aertech
Now TRW Microwave Inc.
Sunnyvale, CA

21962
Vectron Corp.
Replaced by: S.W. Electronics

22526
DuPont, EI DeNemours & Co. Inc.
DuPont Connector Systems
Advanced Products Div.
New Cumberland, PA

22626
Micro Semiconductor
(Now 14552)

22670
GM Nameplate
Seattle, WA

22767
ITT Semiconductors
Palo Alto, CA

22784
Palmer Inc.
Cleveland, OH

23050
Product Comp. Corp.
Mount Vernon, NY

23223
CTS Microelectronics
Lafayette, NY

23237
I.R.C., Inc.
Microcircuits Divison
Philadelphia, PA

23302
S.W. Electronics & Mfg. Corp.
Cherry Hill, NJ

23730
Mark Eyelet and Stamping Inc.
Wolcott, CT

23732
Tracor Applied Sciences Inc.
Rockville, MD

23880
Stanford Applied Engineering
Santa Clara, CA

23936
William J. Purdy Co.
Pamotor Div.
Burlingame, CA

24347
Penn Engineering Co.
S. El Monte, CA

24355
Analog Devices Inc.
Norwood, MA

24444
General Semiconductor
Industries, Inc.
Tempe, AZ

24546
Bradford Electronics
Bradford, PA

24618
Transcon Mfg.
Now: D.J. Associates Inc.

24655
Genrad Inc.
(Replaced General Radio 05173)
Concord, MA

24759
Lenox-Fugle Electronics Inc.
South Plainfield, NJ

24796
AMF Inc.
Potter & Brumfield Div.
San Juan Capistrano, CA

24931
Specialty Connector Co.
Greenwood, IN

24995
ECS
Grants Pass, OR

25088
Siemen Corp.
Isilen, NJ

25099
Cascade Gasket
Kent, WA

25403
Amperex Electronic Corp.
Semiconductor & Micro-Circuit Div.
Slatersville, RI

25435
Moldtronics, Inc
Downers Grove, IL

25706
Daburn Electronic & Cable Corp.
Norwood, NJ

26402
Lumex,Inc.
Bayshore, NY

26629
Frequency Sources Inc.
Sources Div.
Chelmsford, MA

26806
American Zettler Inc.
Irvine, CA

27014
National Semiconductor Corp.
Santa Clara, CA

27167
Corning Glass Works Corning
Electronics
Wilmington, NC

27264
Molex Inc.
Lisle, IL

27440
Industrial Screw Products
Los Angeles, CA

27494
Staffall, Inc.
Providence, RI

27745
Associated Spring Barnes Group Inc.
Syracuse, NY

27918
Component Parts Corp.
Bellmore, NY

27956
Relcom (Now 14482)

28175
Alpha Metals
Chicago, IL

28198
Positronic Industries
Springfield, MO

28213
MN Mining & Mfg. Co.
Consumer Products Div.
3M Center
Saint Paul, MN

28309
Kaiser
Minette,AL.

28425
Serv-O-Link
Euless, TX

28478
Deltrol Corporation
Deltrol Controls Div.
Milwaukee, WI

28480
Hewlett Packard Co.
Corporate HQ
Palo Alto, CA

28484
Emerson Electric Co.
Gearmaster Div.
McHenry, IL

28520
Heyco Molded Products
Kenilworth, NJ

28932
Lumax Industrials, Inc
Altoona, PA

29083
Monsanto Co.
Santa Clara, CA

29604
Stackpole Components Co.
Raleith, NC

29907
Omega Engineering Inc.
Stamford, CT

3D536
Aimsco Inc.
Seattle, WA

30035
Jolo Industries Inc.
Garden Grove, CA

30045
Solid Power Corp.
Farmingdale, NY

30146
Symbex Corp.
Painesville, OH

30148
AB Enterprise Inc.
Ahoskie, NC

30161
Aavid Engineering Inc.
Laconia, NH

30315
Itron Corp.
San Diego, CA

30323
IL Tool Works Inc.
Chicago, IL

30800
General Instrument Corp.
Capacitor Div.
Hicksville, NY

30838
Fastec
Chicago,ILL

31019
Solid State Scientific Inc.
Willow Grove, PA

31091
Alpha Industries Inc.
Microelectronics Div.
Hatfield, PA

31323
Metro Supply Company
Sacramento, CA

31433
Kemet Electonics Corp.
Simpsonville, NC

31448
Army Safeguard Logistics Command
Huntsville, AL

31471
Gould Inc
Semiconductor Div
Santa Clara, CA

31522
Metal Masters Inc.
Baldwin, MS

31746
Cannon Electric
Woodbury, TN

31827
Budwig
Ramona, CA

31918
ITT-Schadow
Eden Prairie, MN

32293
Intersil
Cupertino, CA

32539
Mura Corp.
Westbury, Long Island, N.Y.

32559
Bivar
Santa Ana, CA

32719
Siltronics
Santa Ana, CA

32767
Griffith Plastics Corp.
Burlingame, CA

32879
Advanced Mechanical Components
Northridge, CA

32897
Murata Erie North America Inc.
Carlisle Operations
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Div.
Riverside, CA

33025
M/A ComOmni Spectra, Inc. (Replacing Omni Spectra)
Microwave Subsystems Div.
Tempe, AZ

33096
CO Crystal Corp.
Loveland, CO

33173
General Electric Co.
Owensboro, KY

33246
Epoxy Technology Inc.
Billerica, MA

33292
Pioneer Sterilized Wiping Cloth Co.
Portland, OR

33297
NEC Electronics USA Inc.
Electronic Arrays Inc. Div.
Mountain View, CA

33919
Nortek Inc.
Cranston, RI

34114
Oak Industries
Rancho Bemardo, CA

34263
CTS Electronics Corp.
Brownsville,TX

34333
Silicon General Inc.
Garden Grove, CA

34335
Advanced Micro Devices (AMD)
Sunnyvale, CA

34359
MN Mining & Mfg. Co.
Commercial Office Supply Div.
Saint Paul, MN

34371
Harris Corp.
Harris Semiconductor
Products Group
Melbourne, FL

34576
Rockwell International Corp.
Newport Beach, CA

34641
Instrument Specialties
Euless, TX

34649
Intel Corp.
Santa Clara, CA

34802
Electromotive Inc.
Kenilworth, NJ

34848
Hartwell Special Products
Placentia, CA

35009
Renfrew Electric Co. Ltd.
IRC Div.
Toronto, Ontario, Canada

35986
Amrad
Melrose Park, IL

36665
Mitel Corp.
Kanata, Ontario, Canada

36701
Van Waters & Rogers
Valley Field, Quebec, Canada

37942
Mallory Capacitor Corp.
Sub of Emhart Industries
INpolis, IN

39003
Maxim Industries
Middleboro, MA

4F434
Plastic Sales
Los Angeles, CA

40402
Roderstein Electronics Inc.
Statesville, NC

42498
National Radio
Melrose, MA

43543
Nytronics Inc.(Now 53342)

43744
Panasonic Industrial Co.
San Antonio, TX

43791
Datron Systems
Wilkes Barre, PA

44655
Ohmite Mfg. Co.
Skokie, IL

47001
Lumberg Inc.
Richmond, VA

47379
ISOCOM
Campbell, CA

49569
IDT (International Development & Trade)
Dallas, TX

49671
RCA Corp.
New York, NY

49956
Raytheon Company
Executive Offices
Lexington, MA

5D590
Mostek Corp.
Replaced by: SGS Thompson Microelectronics

5F520
Panel Components Corp.
Santa Rosa, CA

5P575
Nobel Electronics
Suffem, NY

5W664
NDK
Div. of Nihon Dempa Kogyo LTD
Lynchburg, VA

5U802
Dennison Mfg. Co.
Framingham, MA

50088
SGS - Thomson Microelectronics Inc.
Carrollton, TX

50120
Eagle-Picher Industries Inc.
Electronics Div.
CO Springs, CO

50157
Midwest Components Inc.
Muskegon, MS

50356
Teac Corp. of America
Industrial Products Div
Montebello, CA

50364
MMI, Inc.(Monolithic Memories Inc)
Military Products Div.
Santa Clara, CA

50472
Metal Masters, Inc.
City of Industry, CA

50541
Hypertronics Corp.
Hudson, MA

50558
Electronic Concepts, Inc.
Eatontown, NJ

50579
Litronix Inc.
Cupertino, CA

50891
Semiconductor Technology
Stuart, FL

50934
Tran-Tec Corp
Columbus, NE

51167
Aries Electronics Inc.
Frenchtown, NJ

51284
Mos Technology
Norristown, PA

51249
Heyman Mfg. Co.
Cleveland, OH

51372
Verbatim Corp.
Sunnyvale, CA

51398
MUPAC Corp.
Brockton, MA

51406
Murata Erie, No. America Inc.
(Also see 72982)
Marietta, GA

51499
Amtron Corp.
Boston, MA

51506
Accurate Screw Machine Co.
(ASMCO) Nutley, NJ

51605
CODI Semiconductor Inc.
Kenilworth, NJ

51642
Centre Engineering Inc.
State College, PA

51705
ICO/Rally
Palo alto, CA

51791
Statek Corp.
Orange, CA

51984
NEC America Inc.
Falls Church, VA

52063
Exar Integrated Systems
Sunnyvale, CA

52072
Circuit Assembly Corp.
Irvine, CA

52152
MN Mining & Mfg.
Saint Paul, MN

52333
API Electronics
Haugpauge,Long Island,NY

52361
Communication Systems
Piscataway, NJ

52500
Amphenol, RF Operations
Burlington, MA

52525
Space-Lok Inc.
Lerco Div.
Burbank, CA

52531
Hitachi Magnetics
Edmore, MO

52745
Timco
Los Angeles, CA

52763
Stettner-Electronics Inc.
Chattanooga, TN

52769
Sprague-Goodman Electronics Inc.
Garden City Park, NY

52771
Moniterm Corp.
Amatrom Div.
Santa Clara, CA

52840
Western Digital Corp.
Costa Mesa, CA

53021
Sangamo Weston Inc.
(See 06141)

53036
Textool Co.
Houston, TX

53184
Xciton Corp.
Lathan, NY

53217
Technical Wire Products Inc.
Santa Barbara, CA

53342
Opt Industries Inc.
Phillipsburg, NJ

53673
Thompson CSF Components Corp.
(Semiconductor Div)
Conaga Park, CA

53718
Airmold/W. R. Grese & Co.
Roanoke Rapids, NC

53848
Standard Microsystems
Hauppauge, NY

53894
AHAM Inc.
RanchoCA, CA

53944
Glow-Lite
Pauls Valley, OK

54178
Plasmetex Industries Inc.
San Marcos, CA

54294
Shallcross Inc.
Smithfield, NC

54453
Sullins Electronic Corp.
San Marcos, CA

54473
Matsushita Electric Corp.
(Panasonic)
Secaucus, NJ

54492
Cinch Clamp Co., Inc.
Santa Rosa, CA

54583
TDK
Garden City, NY

54590
RCA Corp
Distribution & Special Products
Cherry Hill, NY

54869
Piher International Corp.
Arlington Heights, IL

54937
DeYoung Mfg.
Bellevue, WA

54590
RCA Corp.
Electronic Components Div.
Cherry Hill, NJ

55026
American Gage & Machine Co.
Simpson Electric Co. Div.
Elgin, IL

55112
Plessey Capacitors Inc.
(Now 60935)

55261
LSI Computer Systems Inc.
Melville, NY

55285
Bercquist Co.
Minneapolis, MN

55322
Samtech Inc.
New Albany, IN

55408
STI-CO Industries Co
Buffalo, NY

55464
Central Semiconductor Corp.
Hauppauge, NY

55557
Microwave Diode Corp.
W.Stewarstown, NH

55566
R A F Electronic Hardware Inc.
Seymour, CT

55576
Synertek
Santa Clara, CA

55680
Nichicon/America/Corp.
Schaumburg, IL

55943
D J Associates, Inc
(Replaced Transcon Mfg.-24618)
Fort Smith, AZ

56282
Utek Systems Inc.
Olathe, KS

56289
Sprague Electric Co.
North Adams, MA

56365
Square D Co.
Corporate Offices
Palatine, IL

56375
WESCORP
Div. Dal Industries Inc
Mountain View, CA

56481
Shugart Associates
Sub of Xerox Corp.
Sunnyvale, CA

56637
RCD Components Inc.
Manchester, NH

56708
Zilog Inc.
Campbell, CA

56856
Vamistor Corp. of TN
Sevierville, TN

56880
Magnetics Inc.
Baltimore, MD

57026
Endicott Coil Co. Inc.
Binghamton, NY

57053
Gates Energy Products
Denver, CO

57170
Cambridge Thermionic
Cambridge, MA
Replaced by:
71279
Interconnection Products Inc.

57668
R-ohm Corp
Irvine, CA

57962
SGS - Thomson Microelectronics Inc
Montgomeryville, PA

58014
Hitachi Magnalock Corp.
(Now 12581)

58104
Simco
Atlanta, GA

58364
BYCAP Inc.
Chicago, IL

58451
Precision Lamp
Cotat, CA

58474
Superior Electric Co.
Bristol, CT

58614
Communications Instruments Inc.
Fairview, NC

59124
KOA-Speer Electronics Inc.
Bradford, PA

59422
Holmberg Electronics
Irvine, CA

59610
Souriau Inc
Valencia, CA

59635
HV Component Associates
Howell, NJ

59640
Supertex Inc.
Sunnyvale, CA

59660
Tusonix Inc.
Tucson, AZ

59730
Thomas and Betts Corp.
IA City, IA

59831
Semtronics Corp.
Watchung, NJ

6I1053:
American Components Inc.
an Insilco Co. RPC Div.
Hayesville, NC

6L611
Allen, Robert G. Inc.
Van Nuys, CA

6U850
Burgess Switch Co., Inc
Northbrook, IL

6U095
AMD Enterprises, Inc.
Roswell, GA

6X403
SGS/ATES Semiconductor Corp.
INpolis, IN

6Y440
Micron Technology Inc.
Boise, ID

60046
Power Dynamics Inc
West Orange, NJ

60197
Precicontact Inc.
Langhome, PA

60386
Squires Electronics Inc
Comelius, OR

60395
Xicor Inc.
Milpitas, CA

60399
Torin Engineered Blowers
Div. of Clevepak Corp.
Torrington, CT

60496
Micrel Inc.
Sunnyvale, CA

60705
Cera-Mite Corp.
(formerly Sprague)
Grafton, WI

60911
Inmos Corp.
CO Springs, CO

60935
Westlake Capacitor Inc.
Tantalum Div.
Greencastle, IN

60958
ACIC
Intercomp Wire & Cable Div.
Hayesville, NC

61271
Fujitsu Microelectronics Inc
San Jose, CA

61394
SEEQ Technology Inc.
San Jose, CA

61429
Fox Electronics
Cape Coral, FL

61529
Aromat Corp.
New Providence, NJ

61752
IR-ONICS Inc
Warwick, RI

61772
Integrated Device Technology
Santa Clara, CA

61802
Toshiba
Houston, TX

61857
SAN-O Industrial Corp.
Bohemia, Long Island, NY

61935
Schurter Inc.
Petaluma, CA

62351
Apple Rubber
Lancaster, NY

62643
United Chemicon
Rosemont, IL

62712
Seiko Instruments
Torrance, CA

62793
Lear Siegler Inc.
Energy Products Div.
Santa Ana, CA

63743
Ward Leonard Electric Co.Inc.
Mount Vernon, NY

64154
Lamb Industries
Portland, OR

64155
Linear Technology
Milpitas, CA

64537
KDI Electronics
Whippany, NJ

64782
Precision Control Mfg. Inc.
Bellevue, WA

64834
West M G Co.
San Francisco, CA

64961
Electronic Hardware LTD
North Hollywood, CA

65092
Sangamo Weston Inc.
Weston Instruments Div.
Newark, NJ

65786
Cypress Semi
San Jose, CA

65940
Rohm Corp & Whatney
Irvine, CA

65964
Evox Inc.
Bannockbum, IL

66150
Entron Inc.
Winslow Teltronics Div.
Glendale, NY

66302
VLSI Technology Inc.
San Jose, CA

66419
Exel
San Jose, CA

66450
Dyna-Tech Electronics, Inc
Walled Lake, MI

66608
Bering Industries
Freemont, CA

66891
BKC International Electronics
Lawrence, MA

66958
SGS Semiconductor Corp.
Phoenix, AZ

66967
Powerex Inc
Aubum, NY

67183
Altera
Santa Clara, CA

68919
WIMA
% Harry Levinson Co.
Seattle, WA

7F361
Richmond-Division of Dixico
% Zellerbach Paper Co.
Seattle, WA

7F844
Moore Business Forms, Inc
Seattle, WA

7G902
Textron Inc.
Camcar Div.
Rockford, IL

7J395
Universal Plastics
Welshpool, WA

7J696
AMD Plastics
East Lake, OH

7K354
Omni Spectra Inc
Los Altos, CA

7Z884
ALPS
Seattle, WA

7X634
Duracell USA
Div. of Dart & Kraft Inc.
Valdese, NC

70290
Almetal Universal Joint Co.
Cleveland, OH

70485
Atlantic India Rubber Works Inc.
Chicago, IL

70563
Amperite Company
Union City, NJ

70903
Cooper-Belden Corp.
Geneva, IL

71002
Bimbach Co. Inc.
Farmingdale, NY

71034
Bliley Electric Co.
Erie, PA

71183
Westinghouse Electric Corp.
Bryant Div.
Bridgeport, CT

71279
Interconnection Products Inc.
Formerly Midland-Ross Cambion Div.
Santa Ana, CA

71400
Bussman Manufacturing
Div. McGraw-Edison Co.
St. Louis, MO

71450
CTS Corp.
Elkhart, IN

71468
ITT Cannon Div. of ITT
Fountain Valley, CA

71482
General Instrument Corp.
Clare Div.
Chicago, IL

71590
Mepco/Centralab
A North American Philips Co.
Fort Dodge, IA

71707
Coto Corp.
Providence, RI

71744
General Instrument Corp.
Lamp Div/Worldwide
Chicago, IL

71785
TRW Inc.
Cinch Connector Div.
Elk Grove Village, IL

71984
Dow Corning Corp.
Midland, MI

72005
AMAX Specialty Metals Corp.
Newark, NJ

72136
Electro Motive Mfg. Corp.
Florence, NC

72228
AMCA International Corp.
Continental Screw Div.
New Bedford, MA

72259
Nytronics Inc.
New York, NY

72619
Amperex Electronic Corp.
Dialight Div.
Brooklyn, NY

72653
G C Electronics Co.
Div. of Hydrometals Inc.
Rockford, IL

72794
Dzus Fastner Co. Inc.
West Islip, NY

72928
Gulton Industries Inc.
Gudeman Div.
Chicago, IL

72962
Elastic Stop Nut
Div. of Harrard Industries
Union, NJ

72982
Erie Specialty Products, Inc
Formerly: Murata Erie
Erie, PA

73138
Beckman Industrial corp.
Helipot Div.
Fullerton, CA

73168
Fenwal Inc.
Ashland, MA

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, CA

73445
Amperex Electronic Corp.
Hicksville, NY

73559
Carlingswitch Inc.
Hartford, CT

73586
Circle F Industries
Trenton, NJ

73734
Federal Screw Products Inc.
Chicago, IL

73743
Fischer Special Mfg. Co.
Cold Spring, KY

73893
Microdot
Mt. Clemens, MS

73899
JFD Electronic Components
Div. of Murata Erie
Oceanside, NY

73905
FL Industries Inc.
San Jose, CA

73949
Guardian Electric Mfg. Co.
Chicago, IL

74199
Quam Nichols Co.
Chicago, IL

74217
Radio Switch Co.
Marlboro, NJ

74306
Piezo Crystal Co.
Div. of PPA Industries Inc.
Carlisle, PA

74445
Holo-Krome Co.
Elmwood, CT

74542
Hoyt Elect.Instr. Works Inc.
Penacook, NH

74840
IL Capacitor Inc.
Lincolnwood, IL

74970
Johnson EF Co.
Waseca, MN

75042
TRW Inc.
IRC Fixed Resistors
Philadelphia, PA

75297
Kester Solder Div.
Litton Systems, Inc
Des Plaines, IL

75376
Kurz-Kasch Inc.
Dayton, OH

75378
CTS Knights Inc.
Sandwich, IL

75382
Kulka Electric Corp.
(Now 83330)
Mount Vernon, NY

75569
Performance Semiconductor Corp.
Sunnyvale, CA

75915
Littelfuse Tracor
(Formerly: Tracor-Littelfuse)
Des Plaines, IL

76854
Oak Switch Systems Inc.
Crystal Lake, IL

77122
TRW Assemblies & Fasteners Group
Fastener Div.
Moutainside, NJ

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, IN

77542
Ray-O-Vac Corp
Madison, WI

77638
General Instrument Corp.
Rectifier Div.
Brooklyn, NY

77900
Shakeproof Lock Washer Co.
(Now 78189)

77969
Rubbercraft Corp. of CA Ltd.
Torrance, CA

78189
IL Tool Works Inc.
Shakeproof Div.
Elgin, IL

78277
Sigma Instruments Inc.
South Braintree, MA

78290
Struthers Dunn Inc.
Pitman, NJ

78553
Eaton Corp.
Engineered Fastener Div.
Cleveland, OH

Federal Supply Codes for Manufacturers (cont)

78592
Stoeger Industries
South Hackensack, NJ

79497
Western Rubber Co.
Goshen, IN

79727
C - W Industries
Southampton, PA

79963
Zierick Mfg. Corp.
Mount Kisco, NY

8C798
Ken-Tronics, Inc.
Milan, IL

8D528
Baumgartens
Atlanta, GA

8F330
Eaton Corp.
Cutler Hammer Product Sales Office
Mountain View, CA

8T100
Tellabs Inc.
Naperville, IL

80009
Tektronix
Beaverton, OR

80031
Mepco/Electra Inc.
Morristown, NJ

80032
Ford Aerospace &
Communications Corp.
Western Development
Laboratories Div.
Palo Alto, CA

80145
LFE Corp.
Process Control Div.
Clinton, OH

80183
Sprague Products
(Now 56289)

80294
Bourns Instruments Inc.
Riverside, CA

80583
Hammerlund Mfg. Co. Inc.
Paramus, NJ

80640
Computer Products Inc.
Stevens-Arnold Div.
South Boston, MA

81073
Grayhill Inc.
La Grange, IL

81312
Litton Systems Inc.
Winchester Electronics Div.
Watertown, CT

81439
Therm-O-Disc Inc.
Mansfield, OH

81483
International Rectifier Corp.
Los Angeles, CA

81590
Korry Electronics Inc.
Seattle, WA

81741
Chicago Lock Co.
Chicago, IL

82227
Airpax Corp.
Cheshire Div.
Cheshire, CT

82240
Simmons Fastner Corp.
Albany, NY

82305
Palmer Electronics Corp.
South Gate, CA

82389
Switchcraft Inc.
Sub of Raytheon Co.
Chicago, IL

82415
Airpax Corp
Frederick Div.
Frederick, MD

82872
Roanwell Corp.
New York, NY

82877
Rotron Inc.
Custom Div.
Woodstock, NY

82879
ITT
Royal Electric Div.
Pawtucket, RI

83003
Varo Inc.
Garland, TX

83014
Hartwell Corp.
Placentia, CA

83055
Signalite Fuse Co.
(Now 71744)

83058
TRW Assemblies & Fasteners Group
Fasteners Div.
Cambridge, MA

83259
Parker-Hannifin Corp.
O-Seal Div.
Culver City, CA

83298
Bendix Corp.
Electric & Fluid Power Div.
Eatonville, NJ

83315
Hubbell Corp.
Mundelein, IL

83330
Kulka Smith Inc.
A North American Philips Co.
Manasquan, NJ

83478
Rubbercraft Corp. of America
West Haven, CT

83553
Associated Spring Barnes Group
Gardena, CA

83740
Union Carbide Corp.
Battery Products Div.
Danbury, CT

84171
Arco Electronics
Commack, NY

84411
American Shizuki
TRW Capacitors Div.
Ogallala, NE

84613
FIC Corp.
Rockville, MD

84682
Essex Group Inc.
Peabody, MA

84830
Lee Spring Co. Inc
Brooklyn, NY

85367
Bearing Distributing Co.
San Fransisco, CA

85372
Bearing Sales Co.
Los Angeles, CA

85480
W. H. Brady Co.
Industrial Product
Milwaukee, WI

85840
Brady WH Co
Industrial Products Div
Milwaukee, WI

85932
Electro Film Inc.
Valencia, CA

86577
Precision Metal Products Co.
Peabody, MA

86684
Radio Corp. of America
(Now 54590)

86928
Seastrom Mfg. Co. Inc.
Glendale, CA

87034
Illuminated Products Inc.
(Now 76854)

87516
Standard Crystal
KS City, KS

88044
Aeronautical Standards Group
Dept. of Navy & Air Force

88219
GNB Inc.
Industrial Battery Div.
Langhorne, PA

88245
Winchester Electronics
Litton Systems-Useco Div.
Van Nuys, CA

88486
Triangle PWC Inc.
Jewitt City, CT

88690
Essex Group Inc.
Wire Assembly Div.
Dearborn, MI

88786
Atlantic India Rubber Co.
Goshen, IN

88978
Philips (Now Fluke)
Mahwah, NJ

89020
Amerace Corp.
Buchanan Crimptool Products Div.
Union, NJ

89265
Potter-Brumfield
(See 77342)

89462
Waldes Truarc, Inc.
Long Island, NY

89536
John Fluke Mfg. Co., Inc.
Everett, WA

89597
Fredericks Co.
Huntingdon Valley, PA

89709
Bunker Ramo-Eltra Corp.
Amphenol Div.
Broadview, IL

89730
General Electric
Lamp Div.
Newark, NJ

9R216
Data Composition Svc, Inc
Laurel, MD

9S171
Port Plastics
Tukwila, WA

9W423
Amatom
El Mont, CA

90201
Mallory Capacitor Co.
Sub of Emhart Industries Inc.
Indianapolis, IN

90215
Best Stamp & Mfg. Co.
KS City, MO

90303
Duracell Inc.
Technical Sales & Marketing
Bethel, CT

91094
Essex Group Inc.
Suflex/IWP Div.
Newmarket, NH

91247
IL Transformer Co.
Chicago, IL

91293
Johanson Mfg. Co.
Boonton, NJ

91462
Alpha Industries Inc.
Logansport, IN

91502
Associated Machine
Santa Clara, CA

91506
Augat Alcoswitch
N. Andover, MA

91507
Froeliger Machine Tool Co.
Stockton, CA

91637
Dale Electronics Inc.
Columbus, NE

91662
Elco Corp.
A Gulf Western Mfg. Co.
Connector Div.
Huntingdon, PA

91737
ITT Cannon/Gremar
(Now 08718)

91802
Industrial Devices Inc.
Edgewater, NJ

91833
Keystone Electronics Corp.
NY, NY

91836
King's Electronics Co. Inc.
Tuckahoe, NY

91929
Honeywell Inc.
Micro Switch Div.
Freeport, IL

91934
Miller Electric Co.
Woonsocket, RI

91967
National Tel-Tronics
Div. of electro Audio Dynamics Inc
Meadville, PA

91984
Maida Development Co.
Hampton, VA

91985
Norwalk Valve Co.
S. Norwalk, CT

92218
Wakefield Corp., The
Wakefield, ME

92527
VTC Inc.
Bloomington, MN

92607
Tensolite Co.
Div. of Carlisle Corp.
Buchanan, NY

92914
Alpha Wire Corp.
Elizabeth, NJ

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, MA

94144
Raytheon Co.
Microwave & Power Tube Div.
Quincy, MA

94222
Southco Inc.
Concordville, PA

94988
Wagner Electric Corp.
Sub of Mcgraw-Edison Co.
Whippany, NJ

95146
Alco Electronic Products Inc.
Switch Div.
North Andover, MA

95263
Leecraft Mfg. Co.
Long Island City, NY

95275
Vitramon Inc.
Bridgeport, CT

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, OH

95348
Gordo's Corp.
Bloomfield, NJ

95354
Methode Mfg. Corp.
Rolling Meadows, IL

95573
Campion Laboratories Inc.
Detroit, MI

95712
Bendix Corp.
Electrical Comp. Div.
Franklin, IN

95987
Weckesser Co. Inc.
(Now 85480)

96733
SFE Technologies
San Fernando, CA

96853
Gulton Industries Inc.
Measurement & Controls Div.
Manchester, NH

96881
Thomson Industries Inc.
Port WA, NY

97464
Industrial Retainer Ring
Irvington, NJ

97525
EECO Inc.
Santa Ana, CA

97540
Whitehall Electronics Corp.
Master Mobile Mounts Div.
Fort Meyers, FL

97913
Industrial Electronic
Hardware Corp.
NY, NY

97945
Pennwalt Corp.
SS White Industrial Products
Piscataway, NJ

97966
CBS
Electronic Div.
Danvers, MA

98094
Machlett Laboratories Inc.
Santa Barbara. CA

98159
Rubber-Teck Inc.
Gardena, CA

98278
Malco A Microdot Co.
South Pasadena, CA

98291
Sealectro Corp.
BICC Electronics
Trumbill, CT

98372
Royal Industries Inc.
(Now 62793)

98388
Lear Siegler Inc.
Accurate Products Div.
San Deigo, CA

98978
IERC
(International Electronic Research Corp.)
Burbank, CA

99120
Plastic Capacitors Inc.
Chicago, IL

99217
Bell Industries Inc.
Elect. Distributor Div.
Sunnyvale, CA

99378
ATLEE of DE Inc.
N. Andover, MA

99392
Mepco/Electra Inc.
Roxboro Div.
Roxboro, NC

99515
Electron Products Inc.
Div. of American Capacitors
Duarte, CA

99779
Bunker Ramo- Eltra Corp.
Barnes Div.
Lansdown, PA

99800
American Precision Industries
Delevan Div.
East Aurora, NY

99942
Mepco/Centralab
A North American Philips Co.
Milwaukee, WI

U.S. Service Locations

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Fluke Technical Center
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14180 East Evans Avenue
Aurora, CO 80014
Tel: (303) 695-1171

Florida
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1150 W. Euclid Ave.
Palatine, IL 60067
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5640 Fishers Lane
Rockville, MD 20852
Tel: (301) 770-1576

New Jersey
Fluke Technical Center
East 66 Midland Avenue
Paramus, NJ 07652-0930
Tel: (201) 599-9500

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1801 Royal Lane, Suite 307
Dallas, TX 75229
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Tally Ho Technology Park
East Burwood
Victoria 3151

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Unternehmensbereich Prof. Systeme
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Scientific & Industrial Equip. Div
Service Department.
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Al. Amazonas 422, Alphaville
CEP 06400 Barueri
Sao Paulo
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Santiago 9
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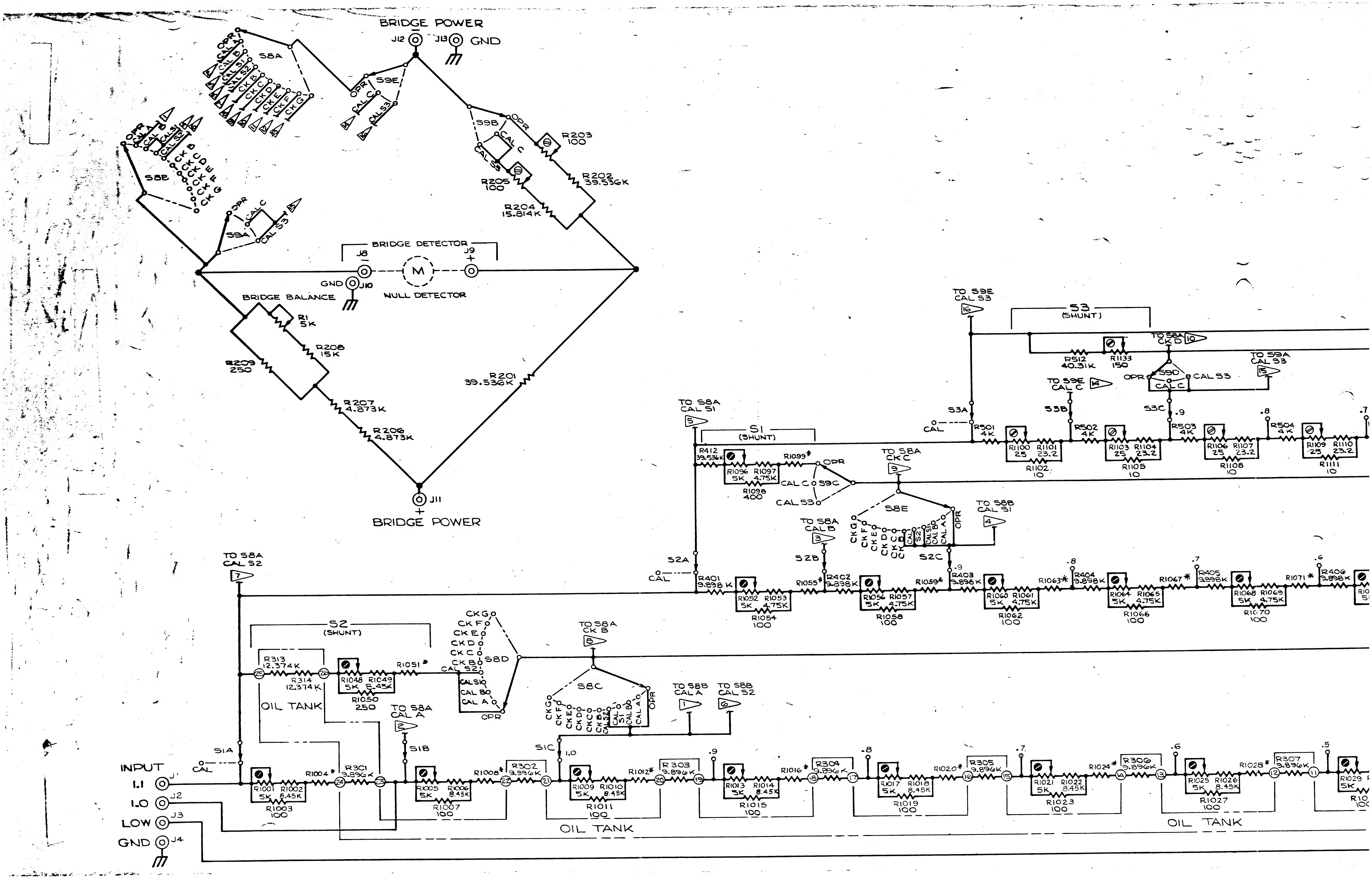
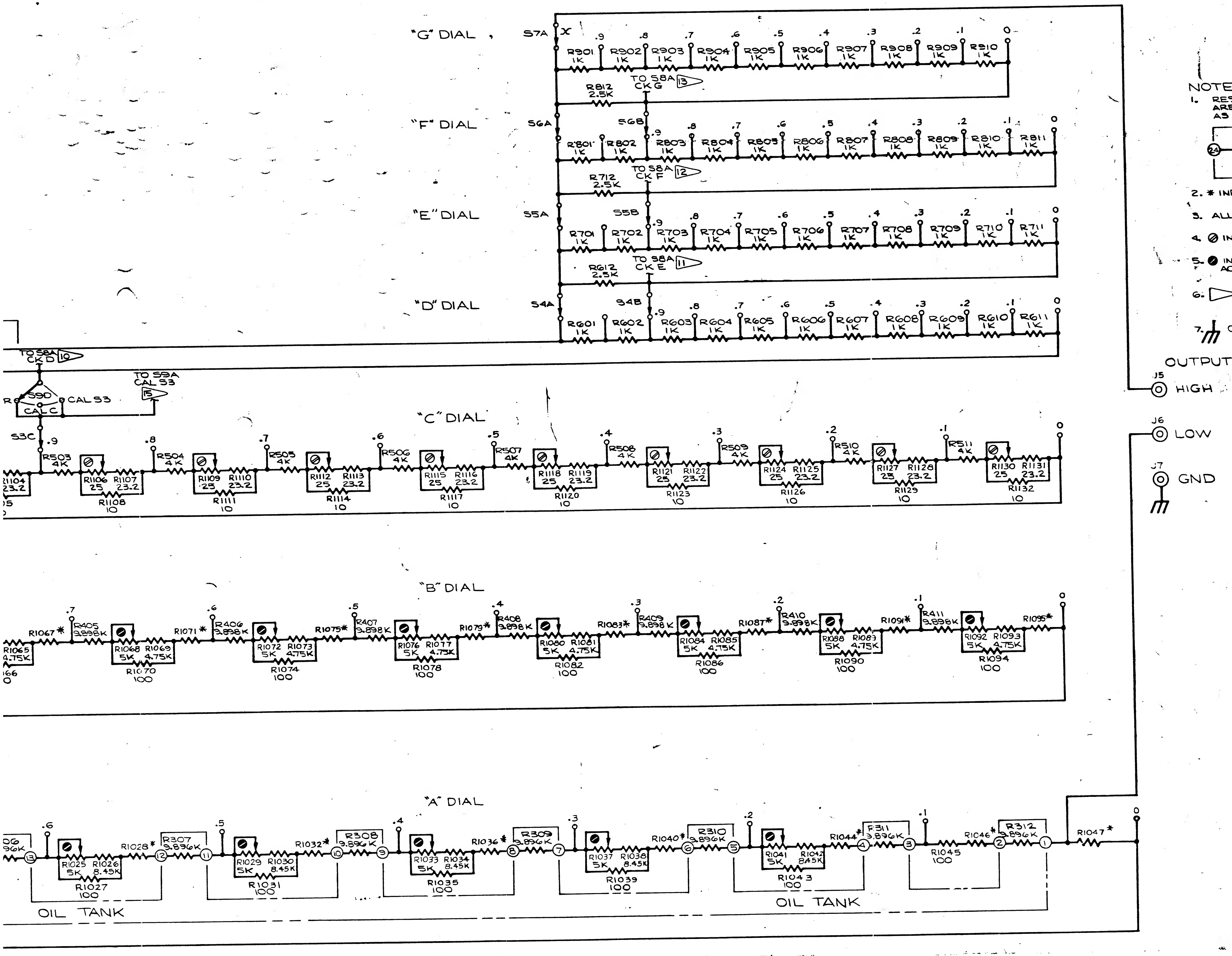


BRIDGE POWER
J12
J13
GND
S8A
S9E
OPR
CAL C
CAL S3
S9B
R203
100
R202
39.536K
R205
100
R204
15.814K
S8B
CK B
CK C
CK D
CK E
CK F
CK G
S3A
BRIDGE DETECTOR
J8
J9
M
GND
J10
NULL DETECTOR
BRIDGE BALANCE
R1
5K
R208
15K
R209
250
R201
39.536K
R207
4.873K
R206
4.873K
J11
BRIDGE POWER
TO S9E
CAL S3
S3
(SHUNT)
TO S8A
CK D
R512
40.31K
R1133
150
TO S8A
CAL S3
TO S9E
CAL C
S9D
S3B
S3C
R501
4K
R502
4K
R503
4K
R504
4K
R1100
25
R1101
23.2
R1102
10
R1103
25
R1104
23.2
R1105
10
R1106
25
R1107
23.2
R1108
10
R1109
25
R1110
23.2
R1111
10
TO S8A
CAL S1
S1
(SHUNT)
R412
39.536K
R1096
5K
R1097
4.75K
R1098
400
R1099*
S9C
TO S8A
CK C
S8E
TO S8B
CAL S1
TO S8A
CAL B
S2B
S2C
S2A
CAL
R401
9.898 K
R1052
5K
R1053
4.75K
R1054
100
R1055*
R402
9.898K
R1056
5K
R1057
4.75K
R1058
100
R1059*
R403
9.898K
R1060
5K
R1061
4.75K
R1062
100
R1063*
R404
9.898K
R1064
5K
R1065
4.75K
R1066
100
R1067*
R405
9.898K
R1068
5K
R1069
4.75K
R1070
100
R1071*
R406
9.898K
TO S8A
CAL S2
S2
(SHUNT)
R313
12.374K
R314
12.374K
R1048
5K
R1049
8.45K
R1050
250
R1051*
OIL TANK
S8D
TO S8A
CK B
S8C
TO S8B
CAL A
TO S8B
CAL S2
TO S8A
CAL A
S1A
S1B
S1C
INPUT
1.1
1.0
LOW
GND
J1
J2
J3
J4
R1001
5K
R1002
8.45K
R1003
100
R1004*
R301
9.896K
R1005
5K
R1006
8.45K
R1007
100
R1008*
R302
9.896K
R1009
5K
R1010
8.45K
R1011
100
R1012*
R303
9.896K
R1013
5K
R1014
8.45K
R1015
100
R1016*
R304
9.896K
R1017
5K
R1018
8.45K
R1019
100
R1020*
R305
9.896K
R1021
5K
R1022
8.45K
R1023
100
R1024*
R306
9.896K
R1025
5K
R1026
8.45K
R1027
100
R1028*
R307
9.896K
R1029
5K
OIL TANK
OIL TANK



NOTES:

1. RESISTORS DESIGNATED R301 THRU R312 ARE ACTUALLY FOUR RESISTORS IN SERIES AS SHOWN BELOW.

R301A 2.474K R301B 2.474K R301C 2.474K R301D 2.474K

OIL TANK

2. * INDICATES FACTORY SELECTED COMPONENT
3. ALL RESISTANCES ARE IN OHMS
4. INDICATES INTERNAL ADJUSTMENT
5. INDICATES INTERNAL ADJUSTMENT ACCESSIBLE THROUGH FRONT PANEL
6. FLAG NOTES WITH THE SAME NUMBERS ARE CONNECTED
7. CHASSIS GROUND

FUNCTIONAL SCHEMATIC DIAGRAM

MODEL 720A

KELVIN-VARLEY VOLTAGE DIVIDER

SER. NO. 123 & ON

REV. b

FLUKE JOHN FLUKE MFG. CO. INC. P.O. Box 7428 Seattle, Wash. 98133